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Our Mineral Problems and the Need for a National Geological Survey.

By David Rivett.

For some time past, special attention has been focussed upon the possibilities of exploiting Australia's resources in metalliferous ores, particularly those carrying gold, which is almost the sole commercial material for which there is to-day an open world market of apparently unlimited extent. Last year in this *Journal*,† a plea was made for sustained and vigorous national effort to produce in quantity this metal, through which there is definite hope of freeing ourselves from our incubus of external debt, or of converting the external into a much more bearable internal debt. Good work has been done by private enterprise; much bad work, too. State Governments, severely handicapped by their financial weakness, have helped; but can any one be satisfied with the total of our progress to date?

Much thought has been given by individuals to the immediate question of how best the Commonwealth Government may assist this definitely national work; many suggestions have been made and most of them rejected on further consideration as inadequate.

There has been the proposal (largely put into effect) for making grants to the States for the support of prospectors equipped with picks and shovels. As a method of handling the unemployment problem, it certainly has attractions; as a means for laying bare our resources it is about equal to the examination of sea fisheries with hand nets; not entirely useless, but depressingly feeble and crude. With highly-trained mining geologists in charge of groups of prospectors, the usefulness of the latter might be increased; but we are short of such geologists. Hence another suggestion has been made that the Commonwealth might send a dozen or more first class young graduates to Harvard University for the special training available there, under Professor D. H. McLaughlin; a good idea, but a long way from a solution to the main problem.

The appointment of a Commonwealth staff to collect and correlate knowledge about existing fields has been proposed, but only to be opposed and rejected.

† Vol. 7, No. 3, August, 1935, page 135.

Useful but limited work has been set in train through the provision of facilities for ore-dressing studies in Kalgoorlie, Adelaide, and Melbourne.

Looking at the situation broadly, however, one is forced to the conclusion that all these proposals have served only to emphasize the outstanding fact that *this country suffers from a fundamental lack of detailed geological knowledge of its mineral resources.* Such a statement does not imply any reflection upon the capacity of the officers of the various State Geological Surveys; it merely says what they themselves know perfectly well, that they have never been given a chance to make an adequate impression upon the huge task in front of them. These Surveys are small, and all are more or less handicapped by heavy routine duties. Much of their splendid stratigraphical work has been correlated and made available in the geological map of Sir Edgeworth David, published in 1933; but David is no more, and his work has only served to emphasize the need for a new attitude towards national geological surveying. His notable effort at continental planning has brought into greater relief the weaknesses of our Australian system of isolated district planning.

Anyone concerned about the development of our mineral resources will appreciate Sir Thomas Holland's Anniversary Address to the Geological Society of London last year. I shall draw on it liberally for advice and help in this argument. "The dominant and underlying object of all official geological surveys," he says, "is the development of the mineral resources of each country that pays for the service." In every country where a national geological survey has been brought into being, the economic development of these resources has been its real object and justification, and "scientific results are either accessory or contributory to this object, or they are by-products." This surely must disarm even the most ardently "practical" critic!

If this development is the *object,* the preparation and continuous improvement of a geological map of the continent is the *method.* What, then, is the minimum personnel of a properly proportioned survey team of sufficient strength to produce adequate results?

Besides the field-mappers or stratigraphers, a reliable map needs the services of palaeontologists, petrologists, and chemists, all men of special training. An ordinary surface or topographical survey can be carried out along lines which are largely stereotyped or mechanical: a few highly trained men can direct numbers of intelligent technicians with field experience but no broad fundamental training, men of non-commissioned rank, let us say. A geological survey is entirely different. It requires almost every officer to be of commissioned standard; the work at every step requires judgment that comes only from thorough and systematic scientific training. The ratio of officers to subordinates is the inverse of that required for a purely topographical survey of contours, areas, &c. It follows from this, too, that the work of isolated prospectors is seldom capable of satisfactory integration by the geologist; the gaps in his records are too great. In the long run, it pays to prepare the geological map only by systematic work by fully trained men. Activities of the hurried syndicate prospecting type usually prove in the end to be but expensive postponements of the essential, real work.

Without going into details about the seven classes of well-defined specialists required for a competent geological survey, and the special varieties thereof needed for problems of coal, oil, and metals respectively, one may state Sir Thomas Holland's conclusion for India, and apply it to Australia, that "the minimum unit for efficient work . . . amounts to 21, with nine or ten more officers to deal with current urgent problems." This includes administration and the control of reference collections.

Canada has provided an outstanding example during the past decade of the immense value, for purposes of mineral exploitation, of a well-organized survey: her team is 35 strong, including six palaeontologists and two mineralogists. The Federal Geological Survey of the United States of America was started by Clarence King (an Englishman), in 1879, with a staff of 24.

What does this signify to us in Australia which, as Holland bluntly reminded his audience, "alone among the Dominions has no national Geological Survey"? It means, to begin with, that although we have half a dozen State Geological Surveys, we have not a single one equipped to do its full job effectively in any one region. I have before me a list of the members of the geological staffs of the respective States. It is unnecessary to give a tabulation; suffice it to say that while between them they might make up an effective minimum team, each staff alone is no more capable of the type of geological survey work for which this country as a whole is desperately in need, than would a group of six men, however well trained for their special stations, be capable of playing a game of football for which the appropriate side strength was eighteen.

As things are at present in Australia, State effort can not give us what we need. Progress requires a relatively large organization working, as Sir Thomas Holland puts it, "in team fashion over large areas." We are unlikely to get this team work from the State Departments, not because of any unwillingness to co-operate, but because their geological staffs are, and will continue to be, fully occupied in work incidental to the inspectorial and other functions of State Mines Departments. These Departments must always have their geologists and chemists: in two States there are as many as five or six geologists, all heavily loaded with routine work. Consequently, they cannot very well unite to form an efficient national team.

There is a place, and there is urgent need, for an Australian Geological Survey, charged with the prime duty of discovering and developing our mineral resources, and particularly our auriferous deposits. How is it to be brought into being? My own view is that the appropriate procedure is for the State Departments of Mines to come together, openly acknowledge the imperative need for a Survey, admit their inability under present financial conditions to meet the situation either severally or collectively, and invite the Commonwealth Government to regard a share in the establishment and maintenance of a Survey as its contribution towards a national policy of mineral development. Some day it *must* be done, and the sooner the better for our national welfare. The co-operation of the Mines Departments could be assured, and so could that of the Universities; and it could be maintained by the creation of a body on lines similar to the now well-established Standing Committee on Agriculture, on which States and Commonwealth work together in very effective fashion.

It is easy to overlook the difficulties of establishing and financing a first-class Survey, and at this stage I am not prepared to give an estimate of its cost; there are people competent to do that at short notice when required. Of one thing we may all be certain, however, and that is that expenditure on such a Survey would ultimately be handsomely repaid, especially during these years (which may not continue indefinitely) of high demand and high price for gold.

That there are huge quantities of "payable gold" in this country, who will doubt? Old-fashioned prospecting, and less old-fashioned but more spectacular *ad hoc* expeditions will continue to achieve some measure of success; but the royal road must be laboriously and systematically laid down if it is to carry the heavy traffic we may reasonably anticipate for it.

Nor is it only gold upon which our attention should be fixed, though there is a great reason at present for putting it in the front rank. Other metals, coal, oil, water, and a large variety of earths and minerals necessary for many manufactures, are worth far more earnest and general attention than we are giving them. If it pays America to spend a million pounds sterling each year on its Federal Geological Survey, apart from the upkeep of numerous State bodies, we need not feel it a rash venture economically to pay *pro rata* to our population, if not to our area, for the growth of knowledge about our own mineral wealth.

If we are to act, let it be at once, for it is hard to believe that there will ever be a greater opportunity for immediate economic return from a national scientific effort of this kind.

Radio Research Board—7th Annual Report.

For the year ended 30th June, 1935.

The Radio Research Board of the Council is constituted as follows:—Professor J. P. V. Madsen (University of Sydney), Chairman; Mr. H. P. Brown (Director-General, Postmaster-General's Department); Electrical Commander F. G. Cresswell (Department of Defence); and Professor T. H. Laby, F.R.S. (University of Melbourne). Its previous Annual Report was published in this Journal (Vol. 7, No. 3: August, 1934).—Ed.

1. General.

Studies of fading and of the behaviour of the ionosphere from the point of view of its reflection of radio waves and investigations concerning atmospherics have been continued. The last year's operations constitute the second year's activities of the three-year period towards the cost of which the Postmaster-General's Department and the Council for Scientific and Industrial Research are contributing on a three to one basis.

Further changes in the staff of the Board have taken place. Early in the period under review, Dr. G. Builder resigned in order to take up an industrial appointment, and Dr. A. L. Green has also notified the Board that he intends to resign in September, 1935, for a similar reason. The Board welcomes this indication of the way its staff is regarded by the industry. Following the resignation of Dr. Builder, Mr. J. H. Piddington, M.Sc., is now engaged on the Board's work in a full-time capacity in Sydney, and as from the 1st July, 1935, Mr. R. W. Boswell, M.Sc., took up a similar appointment at Melbourne.

2. Work on Fading and the Ionosphere.

The investigation of these problems is still centred in New South Wales. As formerly, the object of this work is to investigate the fading of wireless signals. Since the ionosphere is eventually responsible for such fading, it follows naturally that a large part of the programme has been devoted to the examination of its structure and to its diurnal and seasonal fluctuations.

In general, the same points of attack on these problems have been followed as in previous years. During the past year, however, new methods of attack have been developed, while considerable advances in technique have been effected. This year has seen the adaptation of the cathode-ray tube to most of the methods of investigation followed. In particular, it has been found possible to adapt the method of height measurement using high-speed frequency changes outlined in previous reports. This has had the advantage of rendering much of the work independent of the rather cumbersome and delicate Einthoven galvanometer.

During the year, advantage has been taken of the co-operation of Dr. O. O. Pulley, Walter and Eliza Hall Fellow, in the University of Sydney, in order to bring into operation the pulse method of ionospheric

investigation. It is anticipated that the application of this method to some of the problems under investigation will greatly facilitate the interpretation of the results in cases where more than one downcoming wave is being received. Automatic height recording by the pulse method has now been in operation for some weeks, and measurements of the ionisation densities in the various layers of the ionosphere have also been made using this method.

In connexion with the work on the theory of the interaction of radio waves mentioned in the last report, advantage has been taken of the visit to Europe of Associate-Professor V. A. Bailey (University of Sydney) in order to examine the latest observations made on this subject. It has been found that the measurements of Drs. Van der Pol and Van der Mark are in very good agreement with the theory previously outlined, and it has now been possible to obtain therefrom a good estimate of the air pressure in the E region of the ionosphere.

The results obtained with the 3-aerial technique, mentioned in the previous report, have now been analyzed and published. Adequate confirmation has been obtained of the conclusions (1) previously reached from a study of natural fading that there is normally present a considerable degree of lateral deviation of the downcoming rays when reception is at a point not too far distant from the emitting station. The 3-aerial apparatus, however, enables measurements to be made of the polarization of the downcoming ray in addition to its direction of arrival, and it has been found possible, in one specific case, to show that a correlation exists between these two characteristics of the downcoming ray.

This conclusion, which awaits confirmation by further experiments, is nevertheless in good agreement with the theory previously proposed (2), on the influence of the earth's magnetic field on the limiting polarization of the downcoming ray. According to this hypothesis, the measured polarization of the sky ray at the receiver is that acquired by the ray as it leaves the ionosphere. This limiting polarization is, in turn, determined solely by the frequency of the wave relative to the "critical" frequency of the ionosphere and by the direction of propagation of the ray with respect to the lines of force of the earth's field. The occurrence of lateral deviation of the sky ray necessarily entails marked variations in the angle between the downcoming ray and the direction of the earth's field, so that, on theoretical grounds, it should be expected that there is a close connexion between the measured polarization and the direction of arrival of the ray at the receiver.

In the case of symmetrical propagation of the sky ray from Sydney to Liverpool, New South Wales, the angle between the direction of the downcoming ray reflected from the "F" region and the lines of force of the earth's field is approximately 149°. Corresponding to the angles of lateral deviation and of incidence which have been measured by the 3-systems apparatus, this critical angle must have undergone variations between the limits 146° and 154°. Calculations have been made of the degree of ellipticity to be expected in the polarization of the downcoming ray under these conditions, and it has been found that the measured polarization characteristics agree with the theoretical predictions.

This result is of some importance, as it lends support to the use of the theory of limiting polarization on other occasions. It will be recalled that the earlier measurements of circular polarization with a right-handed sense of rotation (3), at Jervis Bay, are also in agreement with the theory, and that more recently an extension of the analysis to cover the propagation of very long waves (4), has resulted in an explanation being put forward of the rotation of the plane of polarization found to occur at sunrise and sunset.

It has been known for some time that Appleton's frequency-change device is somewhat difficult to apply to experimental investigations using very short waves, and it has been suggested (5) that similar results might be obtained if the carrier is modulated and the required frequency-changes imposed on the audio-frequency modulation.

Some preliminary work with the modulation-frequency-change (m.f.c.) technique has been carried out in England and repeated in Australia, and it is clear that the m.f.c. apparatus, as originally designed, suffers several disadvantages when compared with carrier-frequency change (c.f.c.). In general, the amplitude of the artificial fading fluctuations is very small unless subsidiary apparatus is introduced, such as the two square-law detectors employed by Appleton, so that, unless this addition is made, the records are difficult to decipher. Unfortunately, repeated rectification has the effect of greatly enhancing the disturbances due to atmospherics and interference from adjacent transmissions, while, in addition, the recent work has disclosed that the amplitude of the artificial fringes depends in a complicated way both on the intensities and on the relative phases of the ground and sky rays. In the c.f.c. experiments, the relative intensity of the ground and sky rays alone determines the fringe amplitude.

A new m.f.c. technique (6) has therefore been devised which does not require the use of double detection, and in which the fringe records are more simply related to the characteristics of the downcoming ray. In this case, suppression of the carrier is realized at the transmitter instead of the receiver, and only the modulation sidebands are emitted. Since it is not necessary to insert the carrier again at the receiver, it is possible to use the same apparatus there as for the c.f.c. technique.

A number of comparisons have been made of the c.f.c. and the two m.f.c. techniques in ionospheric measurements, and the following conclusions have emerged:—

(i) Both the m.f.c. and the c.f.c. devices measure the same quantity, namely, the equivalent path of the sky ray.

(ii) The amplitude of the fringes produced by a frequency-change in a m.f.c. experiment is much less than in c.f.c., unless subsidiary apparatus is introduced, such as the two square-law detectors employed by Appleton, or the carrier-suppression technique recently developed.

(iii) With either of these modifications, the interference fringe amplitude is occasionally as great as would have been obtained with the c.f.c. technique. Since, however, the fringe amplitude depends on the relative carrier phases of the ground and sky rays, as well as their relative intensities, the fringe amplitude is, on the whole, less when using m.f.c. technique.

(iv) The phase of the beginning of a set of m.f.c. fringes is independent of the momentary state of the natural fading, of the polarization of the sky ray, and of the orientation of the receiving loop aerial. M.f.c. technique is therefore not applicable to those experimental methods, previously developed for c.f.c. work, which depend for their success on the variation of fringe phases with the state of polarization, lateral deviation, and optical path of the sky ray.

(v) It is found that the system using carrier-suppression at the transmitter is the more satisfactory technique for ionospheric investigations, both in regard to apparatus and to the interpretation of records.

The investigations of the Board into the fundamentals of ionospheric propagation have on several occasions suggested methods by which a certain measure of control of wireless signal variations might be effected. The experiments with modulation-frequency-change technique have proved to be closely allied to a known process of controlling fading in wireless telegraphy (7) in which signals are emitted simultaneously on a number of adjacent frequencies. Since it is known that fading variations are different in the case of signals on neighbouring frequencies (8), it follows that a proper choice of the frequencies should result in a balancing of the fading effects in the several channels, and a consequent smoothing of the combined signals.

The most obvious way of sending signals on different frequencies is to modulate the carrier wave at an audible frequency, and thus to emit three waves, carrier and two sidebands. Investigations have shown, however, that it is not possible to obtain perfect control of fading with the simple modulation. The optimum conditions are realized when the depth of modulation is 100 per cent., and when the frequency of modulation is critically adjusted to correspond with the path-difference between the ground and sky rays. Under these conditions, the depth of fading can be reduced to one-third of normal. On the other hand, it has been found that the newly devised suppressed-carrier technique for m.f.c. experiments can easily be adapted to give perfect control of fading. In one instance when the depth of fading was found to be 80 per cent., the addition of control modulation at a frequency of 380 c.p.s. and the suppression of the carrier were found to reduce the fading fluctuations to less than 2 per cent.

It is clear from the theory that the method of control depends on a precise adjustment of the modulation frequency to the path-difference between the interfering rays. It has also been found that the odd-numbered harmonics of the fundamental control frequency are equally effective, but that the even harmonics leave the fading fluctuations undisturbed. It follows that, in certain special cases of the reception of more than one sky ray in addition to the ground ray, it should be possible to suppress one of the sky rays, and to examine the other by experimental methods which are already known. This should facilitate the interpretation of frequency-change records in complex cases.

It would appear that the modulation method of controlling fading has a wider field of application than that mentioned above, that is, as an adjunct to ionospheric research. In long-distance communication, where sky rays alone are receivable, there may be occasions during

which the fading fluctuations are chiefly due to phase interference between two main sky rays (9). When this is so, it should be possible to smooth out the phase fading by a proper adjustment of the modulation frequency to the path-difference between the two main interfering rays.

Experiments have been made in Melbourne and Perth, distant respectively 700 and 3,300 kilometres from the transmitter in Sydney, and it has been found that a considerable improvement in constancy of signal can be obtained with the suppressed-carrier modulation. The communication circuits were first tested with frequency-change signals, and, from the appearance of the photographic records of the received waves, it was immediately obvious that over long periods of time the bulk of the energy was being carried by two main sky rays. In Melbourne, the path-difference between the two main sky rays was approximately 150 kilometres during the afternoon, and 400 kilometres after sunset, there being, however, occasional reversions to the lesser path-difference during the night, and further periods when three sky rays of comparable intensity were being received. Under these circumstances, it was found that a modulation frequency of 200 c.p.s. gave the best results at night over long periods.

The records obtained in Perth were in all cases much more complicated, and it was realized that multiply-reflected rays of high order were present. Nevertheless, after examining a large number of frequency-change test records, it was possible to select a path-difference of about 500 kilometres as representative of the night conditions. The corresponding modulation of frequency 150 c.p.s. was found to effect a considerable influence on the deep troughs of fading. An attempt to allow for a third sky ray resulted in the use of two modulations simultaneously, 50 and 150 c.p.s. A further improvement in constancy of signal was obtained, but it is obvious that a limit to the degree of fading control which can be achieved in long-distance communication is set by the temporal variations in intensity of individual rays.

The application of this system of fading control to telephonic circuits is very much complicated by the presence of the undesired control modulation. So far, no experiments have been made with a programme modulation in addition to the control, but it is interesting to notice that theoretical considerations point to at least one way of effecting the desired result. It has already been mentioned that the odd-numbered harmonics of the fundamental control frequency are also available for the purposes of correction. Experiments with these harmonics up to the 13th have shown that, in practice, it is somewhat difficult to select the modulation frequency with sufficient precision. However, in the case mentioned, it was possible to obtain good fading control when the corrective modulation was actually supersonic, so that it would appear to be possible to add the programme, consisting of audible notes, without interference from the control modulation.

It is perhaps of interest to recall that considerable difficulty was experienced in some early short-wave experiments conducted in Sydney, the transmissions being given from H.M.A.S. *Platypus* (10). Frequency-change signals were sent from the ship, but in no cases were sky rays observed. At that time, it was assumed that propagation conditions in the latitude of Sydney were very different from those previously experienced in England, but it now appears that the absence of sky ray

interference in those experiments was due to a very effective, but unintentional, control of fading, produced by deep modulation of the signals due to the unsmoothed anode supply at the transmitter.

Special attention has been given to the development of stable oscillators. A dynatron oscillator has been built (11) employing temperature compensation in the coils and condenser. This has proved entirely satisfactory, and several beat frequency oscillators have been built using such temperature compensation.

Considerable attention has also been given to methods of obtaining frequency modulation using resistance-tuned oscillators. In this way, it has been found possible to obtain pure frequency modulation of any desired waveform by purely electrical means.

3. Work on Atmospherics.

In the following a *résumé* is given of the information gained from the atmospherics observations made under the administration of the Board.

1. *Origin of Atmospherics.*

Considerable evidence has been adduced in favour of the hypothesis, due originally to Watson Watt, that all atmospherics originate in lightning flashes. This evidence has been confirmed and considerably extended by physicists of the Australian Radio Research Board, from observations taken during a voyage from England to Australia and detailed observations made in Australia relating to the greater part of the continent, the Tasman Sea, and adjacent parts of the Southern Ocean. It has been found ((12) p. 43, (13) p. 28) in the first place, that the points of origin of atmospherics, located by radio direction-finders, always lie within a region which subsequent meteorological reports revealed either that a thunderstorm had occurred or that the conditions made the occurrence of a thunderstorm probable, although none was observed owing to the sparsity of observing stations. This is, however, only a small part of the evidence, for it has been found that single atmospherics, on the one hand, and "sources of atmospherics"* on the other, have exactly the properties to be anticipated from the thunderstorm hypothesis.

2. *Properties of an Atmospheric.*

(i) *Wave-form.*—Appleton, Watt, and Herd concluded from their observations that an atmospheric consists of an aperiodic or "quasi-periodic" pulse lasting a few milliseconds (sometimes with shorter period ripples superposed). Australian observations (14) showed that the total duration of an atmospheric is usually between 0.2 and 0.5 sec., each atmospheric consisting of a succession of the order of 10 pulses of the type found by Appleton, Watt, and Herd, clear intervals separating the pulses. This corresponds exactly to the temporal structure of a lightning flash as deduced from the moving picture photographs of Walter and others. Atmospherics from sea sources have a rather longer average duration. This and other exceptional characteristics of thunderstorms over the sea are referred to later.

* A "source" of atmospherics is a term introduced by Munro and Huxley to denote a well-defined area over which atmospherics arise, which is of linear dimensions of about 100 km. It is a thunderstorm, or a group of thunderstorms which behave as one entity.

(ii) *Polarization.*—Atmospherics are frequently observed to be elliptically polarized, particularly at night. In day time, atmospherics from close sources only show such polarization (15). This property has been used to deduce the mean height of the point of origin of the atmospheric, and a value comparable with the mean height of a lightning flash, as directly observed, is obtained.

(iii) *Equivalent Power of a Flash.*—The term "equivalent power" denotes the power of a station emitting a steady signal which gives the same deflection, on an oscillograph connected to the output of a specified receiver, as the mean deflection produced by atmospherics from a thunderstorm situated immediately over the station. The equivalent power is a function of the frequency to which the receiver is tuned and its band-width of reception.

From the study of intensities of atmospherics from lightning at known distances, it has been found that the equivalent power of a flash (i) is sensibly independent of the geographical area in which the thunderstorm occurs, and has a value of about 2 kw. for a receiver tuned to 1,000 kc/s., and with a band-width of 20 kc/s., and (ii) is inversely proportional to the square of the frequency within the range 10 kc/s.–1,000 kc/s (the band-width being maintained constant).

It is interesting to use this result to estimate the "total peak radiated power" of the flash, i.e., the maximum rate of dissipation of energy in the form of electro-magnetic radiation in the "radio" portion of the spectrum. It is necessary to make some assumption as to what happens at the lower frequencies. The most tractable assumption is that the power falls to zero at a critical frequency V_0, which we shall take as 300 c/s., this being the reciprocal of the period of a single pulse as found by Appleton, Watt, and Herd. With this assumption, integration leads to a value of 10^5 kw. for the total peak radiated power. The peak current in a lightning flash has been variously estimated. If the value of 3×10^5 amps. is assumed, the effective radiation resistance comes out at 10^{-3} ohm.

The range of intensities* of individual atmospherics coming from a single source has been studied ((12) p. 34, (13) pp. 22, 41). It is found that the distribution of logarithms of the intensities is a normal probability distribution, and that 90 per cent. of the atmospherics usually lie within a range of 4 to 1. The range varies slightly with different sources, and appears to be slightly less for 1,000 kc/s. receiver frequency than for 100 kc/s. This relatively small range has led to considerable simplification in the determinations of the mean intensities of sources, i.e., the mean intensity of atmospherics from a source, which have been used in the deduction of equivalent power.

3. *Properties of Sources.*

(i) *Mean Intensities.*—A map, on which points at which lightning flashes give the same mean intensity at the observing station are connected to form "iso-intensity" contours, can be used to determine by interpolation the portion of a source from single station observations, the procedure being somewhat analogous to that used by astronomers in

* The intensity is measured by the oscillograph deflection, with a receiver sensitivity adjusted so that a single-frequency test signal gives a constant deflection.

the case of the Cepheid variable stars. Owing to the relatively small range of individual intensities, a few intensity observations suffice for each source.

(ii) *Extent.*—From carefully selected directional observations, the average extent has been found to be about 10^4 sq. km. ((13) p. 51). Meteorological observers give the area of a thunderstorm as of the order 100 sq. km., but cases are reported of simultaneous occurrence of thunderstorms over an area of the order of 10^4 sq. km. From the number of sources observed in a year's observation in each of several areas and the isobront map for these areas, an independent estimate of the extent of the source can be obtained. The values obtained are of the order of 10^5 sq. km. The discrepancy is probably due to the migration of thunderstorms to which reference will be made later.

(iii) *Activity and Duration.*—The average activity of sources ranges from less than 10 flashes per minute for sources in Tasmania, to over 40 for north-west Queensland. The mean durations of land sources are about 6 hours for all latitudes, but for sea sources the mean is about 10 hours, and some sea sources persist for days. In agreement with direct observations on thunderstorms, the average mid-point in the life of a source is about 4 p.m.

(iv) *Movement.*—As mentioned previously, sources are frequently of a migratory type, moving with velocities of the order 50 km/hr. ((13) p. 51). This point will be considered later in more detail.

4. *Thunderstorm Areas of the World.*

Some information regarding the distribution of world centres of atmospherics was derived from directional observations by Munro and Huxley during a voyage from England to Australia via Suez ((12) p. 19), and this has been confirmed and extended by the records of the atmospheric recorder at Canberra. The most prolific world centre is situated in tropical Africa, the centres next in importance being in the Malay Achipelago and North Australia. Brookes's isobront map, based on reports of meteorological observers, confirm these results.

5. *Distribution in Australia.*

Some light on the detailed distribution of thunderstorms in eastern Australia has been thrown by atmospherics directional observations from Canberra, Melbourne, and Toowoomba. The correspondence obtained with the isobronts deduced by Barkley* from 10 years' meteorological observations is as close as would be expected in view of the limited period of the atmospherics observations.

6. *Interference with Broadcast Reception.*†

Preliminary estimates of the degree of interference with broadcast reception under various circumstances have been made, based on a new definition of degree of interference, viz., the average annual period for which a broadcast listener at a specified place, listening to a signal of specified amplitude, receives more than a specified number of "interfering" atmospherics per minute. Previous estimates of interference have

* Of the Commonwealth Meteorological Bureau.
† A summary of Ref. 13. Paper 2. (pp. 43-60).

always been based on noise level conceptions; these have been shown to be somewhat misleading.

The present estimates are based on the provisional conclusion from experiments that an atmospheric interferes seriously with a broadcast programme when its "peak field intensity" is twice the field strength of the broadcast signal. The equivalent power of a lightning flash (for a specified receiver) being known, and the attenuation of the radiation being obtainable from published data, then for a specified locality, with a broadcast signal of specified field strength and wavelength, a "region of interference" can be determined. Lightning flashes within this region will, on the average, give interfering atmospherics, while flashes outside this region will not. Owing, however, to the appreciable range of radiated powers for a given thunderstorm, thunderstorms from without this region will contribute somewhat to the interference, and allowance must be made on this account.

From the distribution of thunderstorms obtained by isobront maps and atmospherics source data, and the activity and durations of these sources, estimates of degree of interference can then be made. Typical results are for (*a*) Victoria, with signal field strength 0.5 mV/m., wavelength 400 metres, there are 95 hours in the year for which more than 3 interfering atmospherics per minute will occur; (*b*) for south-east Queensland the corresponding figure is 250 hours. In general, for high signal amplitudes, the degree of interference contours correspond closely with the isobronts, while for very low signal amplitudes they correspond nearly to parallels of latitude.

7. *Meteorological Aspects.*†

As mentioned previously, some sources, particularly those south of latitude 35°, show clear evidence of motion. Northern land sources, on the other hand, often appear to be stationary. Meteorologists are accustomed to classify thunderstorms into two types, heat and frontal, the first of which originate from local surface heating, while the second originate in or near a front or frontal zone separating two different air masses. Such fronts are known usually to move with velocities of the order 30-50 km./hr. (although almost stationary fronts are not unknown). A study of the meteorological conditions associated with the sources of atmospherics have enabled many sources to be classified as heat or frontal—in particular, migratory sources all appear to be associated with fronts (as would be expected). The proportion of heat sources increases as the latitude decreases; the thunderstorms of north-west Queensland seem to be mostly heat ones. This conclusion is confirmed by an examination of meterological observers' thunderstorm reports.

In the region below 35° latitude, in late spring and early summer, nearly all sources, if not all, appear to be associated to some degree with fronts, and are consequently of the migratory type, moving roughly from west to east from the Bight to the Tasman Sea. This is interesting in view of the fact that the regularity of movement of fronts and weather phenomena generally in this region constitutes the basis of weather forecasting for Victoria and Tasmania. The area in this

† The data referred to in this section are mostly unpublished.

region which is effectively kept under observation by a cathode ray direction-finder is very large, amounting as it does to some millions of square miles.

8. *Sea Sources.*

The atmospherics observations have shown that the number of sea sources per annum for each 5° "square" (i.e., of latitude and longitude) is comparable with the number of land sources for a square in the same latitude. For the northern part of the Tasman Sea there are rather fewer sea sources than on land, but for the portion of it east of Victoria there is an excess of sea sources.

For obvious reasons sea thunderstorms have been relatively little studied, and it is interesting to summarize the information concerning them given by the atmospherics observations.

The durations of atmospherics from sea sources are almost invariably long, usually of the order of a second; in fact, "sea" atmospherics can usually be distinguished from "land" by this characteristic. As mentioned previously, the average total life of a sea source is also of greater duration than of land. The hours of commencement and ending, and also the hour of greatest activity, are less regular than in the case of land sources. A sea source may continue for days with very slight changes in position, extent, and activity—an example of a sea source persisting over a week has been obtained.

The uniformity of the sea's surface and the comparative independence of the sources on the degree of insolation suggests that sea sources would be almost all of the frontal type. While the meteorological observations tend to confirm this in many cases, the stationary position of many long-lived sources is difficult to reconcile with this usual behaviour of fronts.

9. *Aviation.*

The ability of cathode ray direction-finders to register rapidly the bearings of thunderstorms may have an application to aviation, particularly for night-flying. The movement of sources has been followed in detail on the occasions of two notable flights; in one case an active thunderstorm was situated near, but not on, the route, and in the other case a thunderstorm nearly led to disaster.

4. Publications.

The following publications have been issued during the past year as a result of the Board's investigations:—

(*a*) *Publications of the Council for Scientific and Industrial Research.*

1. *Bulletin* 87.—"Radio Research Board: Report No. 6." (1) "On the Rotation of the Plane of Polarization of Long Radio Waves," by A. L. Green, M.Sc., Ph.D., and G. Builder, Ph.D. (2) "A Field Intensity Set," by A. L. Green, M.Sc., Ph.D., and H. B. Wood, B.Sc., B.E. (3) "Measurements of Attenuation, Fading, and Interference in South-Eastern Australia, at 200 Kilocycles per Second," by G. H. Munro, M.Sc., and A. L. Green, M.Sc., Ph.D. (4) "A Frequency Recorder," by D. F. Martyn, Ph.D., A.R.C.Sc., and H. B. Wood, B.Sc., B.E.

2. *Bulletin* 88.—"Radio Research Board: Report No. 7." (1) The Propagation of Medium Radio Waves in the Ionosphere," by D. F. Martyn, Ph.D., A.R.C.Sc., (2) "The Characteristics of Downcoming Radio Waves," by D. F. Martyn, Ph.D., and A. L. Green, Ph.D. (3) "The Influence of Electric Waves on the Ionosphere," by V. A. Bailey, M.A., D.Phil., and D. F. Martyn, Ph.D. (4) Long Distance Observations of Radio Waves of Medium Frequencies," by D. F. Martyn, Ph.D., R. O. Cherry, M.Sc., and A. L. Green, Ph.D.

3. *Bulletin* 89.—"Radio Research Board: Report No. 8." (1) "Simultaneous Observations of Atmospherics with Cathode-Ray Direction-Finders at Toowoomba and Canberra," by G. H. Munro, M.Sc., and H. C. Webster, M.Sc., Ph.D., and A. J. Higgs, B.Sc. (2) "Atmospheric Interference with Reception," by W. J. Wark, M.Sc.

(*b*) *Other Publications.*

1. "Dispersion and Absorption Curves for Radio Wave Propagation in the Ionosphere according to the Magneto-Ionic Theory," by D. F. Martyn, Ph.D., A.R.C.Sc. *Phil. Mag.*, **19**: 376, 1935.

2. "The Interaction of Radio Waves," by V. A. Bailey, M.A., D.Phil., and D. F. Martyn, Ph.D., A.R.C.Sc. *Wireless Engineer*, March, 1935.

3. "The Interaction of Radio Waves," by V. A. Bailey, M.A., D.Phil., and D. F. Martyn, Ph.D., A.R.C.Sc. *Nature*, **135**: 585, 1935.

4. "A Temperature Compensated Dynatron Oscillator of High Frequency Stability," by J. H. Piddington, B.Sc., B.E. *J. Inst. Eng. Aust.*, **6**: 1934.

5. "The Amplification of Transients," by G. Builder, Ph.D. *Wireless Engineer*, **12**: 246, 1935.

6. "A Graphical Solution of Simple Parallel-Tuned Circuits," by G. Builder, Ph.D. *J. Inst. Eng. Aust.*, **6**: 1934.

7. "A Multi-Range Push-Pull Thermionic Voltmeter," by G. Builder, Ph.D. *J. Inst. Eng. Aust.*, **6**: 1934.

8. "The Amplification of Programme Transients," by G. Builder. *J. Inst. Eng. Aust.*, **6**: 1934.

5. Acknowledgments.

Once again, acknowledgment is due to a number of organizations and individuals for the valuable co-operation they have furnished. The help of the Postmaster-General's Department and of the Universities of Melbourne and Sydney has been continued on the previous lines. The Department of Defence, too, has afforded help in several ways, notably by the loan of apparatus and the accommodation of equipment at Laverton (Victoria), and Liverpool (New South Wales). The Commonwealth Solar Observatory at Mt. Stromlo, and the Watheroo Magnetic Observatory of the Carnegie Institution are also co-operating most helpfully in connexion with the work on atmospherics. The Commonwealth Meteorological Bureau has also furnished meteorological data at all times, and towards the end of the period under review, arranged to co-operate in a thorough test of the possible value of the Board's atmospheric work from a meteorological point of view.

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12. "Radio Research Board Report No. 5," Coun. Sci. Ind. Res. (Aust.), Bulletin No. 68.
13. "Radio Research Board Report No. 8," Coun. Sci. Ind. Res. (Aust.), Bulletin No. 89.
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Breakdown in Tasmanian Apples.*

By W. M. Carne† and D. Martin, B.Sc.†

This paper reports some of the more important results so far obtained in an investigation of non-parasitic wastage in Tasmanian apples. Though commenced in 1928-29, intensive work has been confined to the last three seasons. Of these, 1932-33 had a cool wet summer, 1933-34 one warm and exceptionally dry, and 1934-35 warm with a very high rainfall. The work has been based upon the study of the fruit of individual trees, on selected soil types, of varieties with high, intermediate, and low susceptibility to non-parasitic wastage. The method has been to conduct a series of tests on weekly or fortnightly samples, combined with a limited number of storage trials from each tree. Sampling has been commenced at stages of definite immaturity, and carried on as long as the crop lasted. Of the nine varieties used, Cox's Orange Pippin has been the more intensively studied because of its economic importance and high susceptibility to wastage.

It should be understood that in Tasmania, unlike on the Australian mainland, there has not been any marked seasonal alternation of the size of the apple crop. There are heavier and lighter years, due largely to climatic variations and the incidence of wastage from insects, fungi, &c., in different years, but not to a marked alternation of crop. In any season in any planting of one variety, it is possible to find trees with "on" and "off," and, in many, intermediate crops. The selected trees of the varieties studied intensively have been in groups, comprising some with "on" and "off" crops each season.

Tasmanian apples exhibit certain marked features in regard to wastage in overseas, mainland, and local markets, and in local stores, both common and refrigerated. Early shipments overseas of certain varieties, notably Cox's Orange Pippin, are reported each season to arrive or become more or less pitted and "over-ripe and wasty." Later shipments arrive less "ripe," and even immature. In certain seasons, "over-ripeness" and "wastage" is more or less general in many varieties sent overseas throughout the market period, becoming progressively worse as that for each variety advances. In the same seasons, a similar wastage occurs in apples sent to mainland markets; and in the same seasons and in the same varieties, loss from breakdown is heavy in local cool and common stores; 1933 was a season of this type. 1934 and 1935 were by comparison remarkably free from general wastage in both experimental and commercial lots. Even in years of good average keeping, some "wastage" and "over-ripeness" is reported from mainland markets in a few varieties, notably Jonathan, from May onward. Much of this wastage occurs in fruit picked relatively late, and shipped directly from, or after being held at normal air temperatures in, the orchards. This particular class of wastage is usually less in fruit which has been picked earlier and held in cool storage.

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* Paper read at the Imperial Botanical Conference, August, 1935.

† Officers of the Division of Plant Industry, C.S.I.R., accommodated at the University of Tasmania, Hobart.

From the work of Dr. J. Barker on Tasmanian apples in England, and from personal experience of Tasmanian apples in Tasmania, on the mainland, and in England, it is possible to say with the greatest confidence that much, if not most, of the so-called "over-ripeness" referred to above is, in fact, breakdown. By breakdown is meant a non-parasitic browning and softening of unexposed tissues. That over-ripeness and breakdown are not interchangeable terms is best shown by the fact that serious breakdown in Tasmanian apples is almost invariably greater after storage at 32°-34° F. than at higher cool storage temperatures (38°-40°), or even at room temperature (50°-70°). In our experiments, the ratio of wastage in breakdown-susceptible varieties at 32°-34° as compared with 38°-40°, has rarely been less than 2:1, and is frequently as high as 5:1, and has been much higher. After three weeks at 50°-55° following ten weeks at 32°-34°, wastage to the extent of 50 per cent. of the fruit of susceptible varieties has not been uncommon, and has been up to 100 per cent. in experiments. It should be pointed out that the above storage period has been standardized for varieties of which the major part of the crop is exported overseas. The post cool-storage period of three weeks is designed to simulate in some degree the distribution period overseas and in mainland markets. In all forms of breakdown we have found, especially for storage periods up to three months, that the condition of the fruit when in, or immediately after, removal from cool store, is no indication of its true condition. Most of the breakdown develops as the fruit reaches air temperature, the rate rising with the temperature. This is in agreement with Dr. J. Barker's work in England, where he showed that little breakdown was usually found when the fruit was unloaded from ships, but that it might increase to a very serious extent during the following two or three weeks.

It is not implied that over-ripeness *per se* does not occur. It does; but in our experience it is much less serious than reports suggest.

Experience has shown that the facts outlined above are due in the main to the following:—

(*a*) A number of the more important apple varieties grown in Tasmania are subject to low temperature breakdown. This liability varies in different seasons, and is undoubtedly the main cause of the seasonal variation in the average wastage of Tasmanian apples. When liability is present, the lower the temperature of storage the greater the incidence of breakdown. Other factors relative to its incidence will be dealt with later.

(*b*) The presence of bitter pit in varieties subject to this disorder is the cause of a second type of breakdown. By itself, bitter pit breakdown occurs more rapidly at higher than lower storage temperatures, so that fruit so affected has usually a better out-turn from low temperatures than high. During the post-storage period at normal temperatures, this advantage usually disappears. When varieties, such as Cox's Orange Pippin and Ribston Pippin, which have a high liability to low temperature breakdown, are also pitted, the results of cool storage are different. The presence of bitter pit (and of the chemical and physical features which accompany it) raises the liability to low

temperature breakdown. Thus even in years of relatively low general liability to low temperature breakdown, the wastage from breakdown is much greater in pitted lines held at lower temperatures than at higher.

(*c*) The third important form of breakdown concerns mostly late picked fruits of varieties subject to one of the forms of water core. Of these, Jonathan, King David, and French Crab are outstanding. The presence of water core results in loss from breakdown which varies with the variety and the severity and distribution of water core in the fruit. Like that following bitter pit, this breakdown develops more rapidly, but not necessarily to a greater final extent, in fruit held at higher than lower storage temperatures. When liability to low temperature breakdown is also present, as it is normally in Cox's Orange Pippin, and, in some years, in French Crab and Jonathan, breakdown is much more serious at lower than higher temperatures. Late picked fruit of most varieties is usually sent to mainland markets directly, and it is less frequently placed in cool stores or shipped overseas. There is no doubt that the occurrence of breakdown in lines of Jonathan, King David, and French Crab, which usually occurs in the mainland markets each season from about May, is largely due to water core in the fruit when picked. This is particularly so in seasons such as the last two, when liability to low temperature breakdown in these varieties has been unimportant.

(*d*) Other things being equal, liability to the three forms of breakdown mentioned above is greatest in the fruit from the trees with lightest crops. Such fruit is an important factor in the degree of wastage in any line of a susceptible variety. Further, such fruit ripens to the eye and taste earlier, and is larger than the fruit from heavier crops grown under the same conditions. Hence the normal selective picking of the larger more advanced fruits for earlier shipment means that such shipments are largely obtained from light cropped trees. It follows that such shipments are more likely to develop breakdown than those from heavier crops shipped later. It is undoubtedly the main reason for the usual greater occurrence of so-called "over-ripeness" in Cox's Orange Pippin and Ribston Pippin in earlier than in later shipments.

The following conclusions relative to the incidence of breakdown are based mainly on the study of Cox's Orange Pippin grown under natural rainfall. Our experience, however, indicates that they apply to other varieties liable to breakdown when allowance is made for the difference in varietal liability, and for specific varietal features. In French Crab, for instance, alternate bearing is so marked that little or no fruit is carried by trees in their "off" year:—

1. Liability to all forms of breakdown varies inversely with the size of the crop on individual trees grown under similar conditions. With alternately bearing trees, the "on" crop is far superior to the "off" crop, with medium crops

intermediate in storage capacity. With Cox's Orange Pippin and Ribston Pippin at least, the evidence indicates that provided only the "on" crop is exported or stored, alternate is superior to regular cropping. This does not necessarily apply to varieties with a lower liability to breakdown.

2. Liability to low temperature breakdown is greatest in seasons of relatively low summer temperatures; 1932-33 was a year of high, and 1933-34 and 1934-35 years of relatively low, liability. Data extending back to 1928-29 indicate that the best years have been those of relatively high mean temperatures in January and February. The seasonal variation in low temperature breakdown determines the variation in total breakdown.

3. As between trees under the same conditions in the same season, the liability to breakdown has been inversely related to the size of the crops.

   As between seasons, liability in the fruit of any tree has been a product of the season and the crop. In seasons of high level of liability, light crop fruit may have a liability resulting in 100 per cent. breakdown.

   As between trees of similar crop on different soils, but subject to very similar climatic factors, differences in liability of the fruits occur. These appear to be mainly due to differences in the physical character of the soils as they relate to root depth, water penetration, drainage, &c. It is not certain to what extent these operate directly, but they certainly do operate indirectly through affecting the incidence of bitter pit. It may be stated generally that, other things being equal, the soils of better type produce fruit of better keeping quality than those of poorer type. The effects of chemical differences in soils appear to be less important.

   For the same tree, liability to breakdown increases with the maturity of the fruit when picked, at least within the normal picking season.

   For the same tree, liability is greater in larger than in smaller fruits. Larger fruits from heavy crops are less liable than smaller fruits from light crops grown under the same conditions.

4. For varieties very susceptible to low temperature breakdown, storage at 32°-34° is always inadvisable. This applies also to less susceptible varieties in seasons with cool summers. In such seasons, 38° appears to be the minimum safe temperature unless the fruit is picked very early, when the temperature may be somewhat lower.

   Very susceptible varieties include Cox's Orange Pippin and Ribston Pippin; and susceptible varieties, Jonathan, Scarlet, Sturmer, and French Crab. Resistant varieties are Worcester Pearmain, Democrat, and Crofton. Cleopatra is resistant except when pitted, and Delicious except when severely affected with water core.

5. Resistant varieties are characterized by a relatively low level of titratable acidity. The reverse occurs in susceptible varieties grown in the same season and in the same soils. The general level of acidity was significantly higher for groups of trees of one variety in 1933 than in 1934 or 1935. In each year the level for the fruit of a light crop was higher than that of heavy crops grown under similar conditions. The same relation has been found with respect to soluble carbohydrate content.

6. Fruit from light crop trees as compared with that from heavy crops grown under the same conditions averages larger, and is more advanced in ground colour changes and in flavour and aroma, but loses its starch later.

Therefore, the evidence indicates that relatively high acidity, high content of soluble carbohydrates, and slow rate of starch loss accompany high susceptibility to breakdown of all three types. As such conditions appear to go with seasons of summers of below normal temperatures in January and February, it should be possible from tests of representative samples of fruit before picking commences, and from a study of climatological data, to predict the relative incidence of breakdown in any season. During the last two seasons, predictions of this kind have been made with considerable accuracy. Though further confirmation is necessary, there is no doubt that the adoption in some degree of the recommendations which follow would definitely reduce the wastage in Tasmanian apples shipped out of the State or stored locally.

1. Apples should be picked, stored, or shipped in relation to the varieties concerned, their liability to breakdown, the crops on individual trees, and the seasonal climate.

2. Light and, on poorer soils, even moderately light trees of Cox's Orange Pippin or Ribston should not be picked for export or storage. Light crops of other varieties subject to pit or breakdown should also be discarded or sold for immediate consumption.

3. Jonathan, Cox's Orange Pippin, Ribston Pippin, Sturmer, Scarlet, French Crab, and other varieties which in the future may be found susceptible to low temperature breakdown, should be picked for storage or export as early as may be reasonable in seasons of cool summers. In any year French Crab should be picked not later than March for storage or export.

4. Jonathan, King David, and other varieties subject to water core as they ripen should be picked before this disorder becomes present. Light crop trees should be picked before heavier.

5. In local stores, Jonathan, Sturmer, and Scarlet should be segregated from other varieties not subject to low temperature breakdown in seasons following cool summers. (Cox's Orange Pippin and Ribston Pippin are not stored, as there is little market for them in Australia.) In such seasons the temperature of storage for these varieties should not fall below 36°–38°, according to the probable liability to breakdown. As green apples, like French

Crab, lose value as they colour, this variety should be picked very early in such seasons to offset liability to breakdown at 33°–34°. If segregation of varieties is not possible, a general temperature of 35°–36° after cool summers, and 33°-34° after warm summers would be an improvement.

6. The difficulty of segregating varieties on ships, and of providing temperatures with a reasonably low range within holds, is recognized. Nevertheless, two matters would appear to justify consideration in relation to apple export from Tasmania. The high market value of Cox's Orange Pippin in London, and its extreme susceptibility to wastage would justify attempts to secure special chambers for this variety. To secure sufficient quantities of fruit to fill, say, a 'tween deck, Ribston could be grouped with this variety profitably. For such chambers, the nominal temperature should be about 37°-38° as against the usual 33°-34° for apples. Further, in seasons following cool summers, if segregation of varieties is impossible, attempts should be made to have the more susceptible varieties stowed in the warmer parts of the hold, or to secure the adoption of a nominal temperature of, say, 35°-36°.

The main new points in relation to breakdown dealt with in this paper are:—

The effect of seasonal climate on the acidity and soluble carbohydrate level and on breakdown in apples.

The effect of crop size on breakdown, acidity, and soluble carbohydrates, and rate of starch loss in apples.

The necessity in breakdown-liable varieties of handling fruit on the basis of seasonal climate and crop per individual tree.

Apple Investigations in Tasmania: Miscellaneous Notes.*

By W. M. Carne† and D. Martin, B.Sc.†

7. The Safe Limit of Carbon Dioxide Concentration under Ordinary Cool Storage Conditions.

Summary.

Progress is reported on experiments in Tasmania with apples stored at 32° and 34° F. in atmospheres containing different concentrations of respired carbon dioxide.

In 1935 it was found that some injury may occur at 32°F. with concentrations of carbon dioxide as low as 3 per cent.

Of the three varieties used, French Crab proved to be the most, and Jonathan the least, susceptible to injury, with Sturmer intermediate.

In general, concentrations of 2 to 3 per cent. gave a better out-turn after 8 weeks' cool storage than lower or higher concentrations.

On the available data, a concentration of 2 per cent. carbon dioxide would appear desirable for apples held at 32°F. for storage periods equivalent to those usually experienced by apples shipped overseas.

Introduction.

The condition known as brown heart was first recorded in England from Australian apple shipments in 1911. In 1918, Kidd and West (2) reproduced it experimentally, and demonstrated its relation to excessive carbon dioxide in the storage atmosphere. When, therefore, serious damage occurred in Australian shipments in 1922, these authors were able to recognize both the disorder and its cause.

Following an expedition to Australia in 1923, the same workers placed the safe upper limit of carbon dioxide at 10 per cent. to avoid brown heart in apples in refrigerated holds (3). In 1930, they suggested (4) that an upper limit of 5 per cent. might be desirable because of the probable effect of higher concentrations on the liability of apples to low temperature breakdown. This arose from the finding that 5 to 10 per cent. carbon dioxide increased the liability to low temperature breakdown of Bramley's Seedling grown in England (5). Sturmer in New Zealand is affected in the same way (6).

Kidd and West found that the severity of brown heart increased with increasing carbon dioxide provided oxygen was present, that apples were more susceptible at lower than at higher temperatures, and that apples exposed late in their storage life to conditions favourable to brown heart were less susceptible than when exposed earlier.

Little information is available concerning the varietal susceptibility of Australian apples to brown heart, and none on the effect of carbon dioxide on their liability to low temperature breakdown. Brown heart

* Continued from page 224 of the August issue of this Journal.

† Officers of the Division of Plant Industry, C.S.I.R., accommodated at the University of Tasmania, Hobart.

has been recorded in England in the following varieties from Australia:—Cox's Orange Pippin, Cleopatra, Sturmer, French Crab, Ribston Pippin, Scarlet, London Pippin, Adam's Pearmain, Duke of Clarence, Granny Smith, King David, Dunn's, Crow Egg, Hollow Crown, and Jonathan. Of these, the first six appear to have been the most affected.

Experiments with Australian Apples.

A small scale test was carried out with Australian apples *en route* to England in 1925 (3). They were stored at 34°-38° F. in 14, 19, and 25 per cent. carbon dioxide for 68 days. The results showed that Cleopatra, Cox's Orange Pippin, London Pippin, Sturmer, and Adam's Pearmain were more affected by brown heart than Scarlet, King David, and Dunn's.

The limited data available therefore indicated that there was little danger of brown heart in overseas shipments of Australian apples, provided the carbon dioxide content of the storage air did not rise above 10 per cent. There was, however, a possible danger from increased liability to low temperature breakdown, if the carbon dioxide content rose above 5 per cent. To obtain more definite information, experiments were initiated in Tasmania in 1934. They were designed primarily to provide data as to the safe upward limit of carbon dioxide at temperatures, and for storage periods, as are experienced by apples shipped overseas from Tasmania in refrigerated holds. In relation to the possible effect of carbon dioxide on breakdown liability it is of interest that these experiments, and others with fruit from the same source, showed that liability to low temperature breakdown was low under ordinary storage conditions in 1934 and 1935, but high for these varieties in 1933. It is proposed to continue the experiments at least until a season is experienced with a breakdown liability similar to that of 1933. The present is therefore a progress report.

Method.—Air-tight pulp tins (43 lb.) were tapped with glass tubes to enable air to be withdrawn from either top or bottom. In each tin, 25 apples of 2½ inch size, in anti-scald oiled wraps, were placed, occupying approximately one quarter of the interior space. The circular set-in lids were held in place by solder, and the joins sealed with wax. The carbon dioxide content was allowed to accumulate until it reached a pre-determined level at 50°–60°F., and then held there, with the tins in cool store, by blowing in air daily. The concentration was determined daily by means of an Orsat-Fischer apparatus. The fluctuation from the pre-determined level was usually about 2 per cent. at the lower and 1 per cent. at the higher figures. Difficulties were experienced in some cases. Air leakage occurred in French Crab E–2 during the first half of the storage period, and some difficulty was experienced in maintaining high concentrations in Jonathan A–1. The air for sampling was drawn from the bottom of the tins, but tests showed no appreciable difference when it was drawn from the top. As far as possible two tins in each series were held at the same concentration.

The tins, together with 50 fruits for a control in each series, were placed in a commercial cool storage chamber kindly placed at our disposal by the management of the Moonah Cool Stores Pty. Ltd.

The mean storage temperature was 34°F. in 1934 and 32°F. in 1935, the variation from the mean rarely exceeding 2°. The storage periods were 10 and 8 weeks respectively. The concentrations of carbon dioxide are shown in the tables that follow. Where the difference in the mean concentrations of a pair of tins did not exceed 1 per cent., the results have been combined.

Material.—The fruit in each series came from the same group of trees. The A series came from trees giving fruit which storage experiments showed to have a high liability to low temperature breakdown in 1933, but not in 1934 and 1935. Sturmer B came from a plot giving fruit with a low susceptibility to low temperature breakdown in the three seasons 1933 to 1935. Jonathan B had a history of susceptibility to breakdown or deep scald prior to 1934.

French Crab is a green early to mid-season culinary variety, of high acidity; Jonathan a mid-season, medium-acid, red dessert, and Sturmer a late, high-acid, yellow, dual purpose variety.

The accompanying tables present data on carbon dioxide concentration and the incidence of low temperature breakdown, brown heart, and alcoholic poisoning (1).

STURMER A–1, 1934.

Picked 28 May. Cool Stored 31 May. Ex Store 10 August. Final Examination 31 August.

Lot.	Mean % CO_2.	% Sound.	% Alcoholic Poisoning.	% Brown Heart.
A	5·5	100	..	..
B	10	96	4 sl.	2 sl.
C–2	13·8	80	8	16
C–1	15	32	44	56
E–2	18·4	8	40	92
D–1	19·8	..	56	96
D–2	20·6	..	92	100
E–1	24·4	..	100	100
Control	0·6	100	..	..

Percentage wastage due to brown heart only	30
„ „ alcoholic poisoning only	7
„ „ brown heart plus alcoholic poisoning	63

STURMER A–2 AND 3, 1935.

A–2—Picked 29 April. Cool Stored 1 May. Ex Store 27 June. Cut 11 July.

Lot.	Mean % CO_2.	% Sound.	% Alcoholic Poisoning.	% Brown Heart.
A	2·2	100	..	..
B	5·5	96	..	4
C	9·3	22	2	78
D	13·3	6	12	94
E–1	17	..	32	100
E–2	19·5	..	40	100
Control	0–1	100	..	..

A–3—Picked 20 May. Cool Stored 28 May. Ex Store 24 July. Cut 6 August.

Lot.	Mean % CO_2.	% Sound.	% Alcoholic Poisoning.	% Brown Heart.
A	1·8	100	..	..
B	5·5	100	..	..
C	9·5	40	..	60
D	13·6	..	12 v.sl.	100
E–2	16·4	..	4 ,,	100
E–1	19	..	16 ,,	100
Control	0–1	100	..	..

Sturmer B, 1935.

Picked 13 May. Cool Stored 16 May. Ex Store 12 July. Cut 5 August.

Lot.	Mean % CO_2.	% Sound.	% Alcoholic Poisoning.	% Brown Heart.
A	2	92	..	8
B	5·5	54	2 v.sl.	46
C	9·9	..	..	100
D	13·3	..	..	100
E	18·7	..	..	100
Control	0–1	100	..	..

French Crab, 1935.

A–1—Picked 23 February. Stored 26 February. Ex Store 23 April. Cut 2 May.

Lot.	Mean % CO_2.	% Sound.	% Alcoholic Poisoning.	% Brown Heart.
A	2·7	96	..	4 v.sl.
B†	6·4	56	..	44 v.sl.
C†	10	90	..	10 sl.
D	14	12	82	54 (40 sl.)
E–1	18.5	..	100	72 (28 sl.)
E–2	18.8*	36	44	64 (48 sl.)
Control	0–1	100	..	..

A–2—Picked 25 March. Stored 28 March. Ex Store 23 May. Cut 29 May.

Lot.	Mean % CO_2.	% Sound.	% Alcoholic Poisoning.	% Brown Heart.
A	2·9	86	6 v.sl.	8 (4 sl.)
B	6·4	40	43	34 (14 sl.)
C	10	20	72	76
D	13·7	10	72	90
E	18·6	..	100	100
Control	0–1	92	..	8 v.sl.

Percentage wastage due to brown heart only 32 A–1 14 A–2
,, ,, ,, alcoholic poisoning only .. .. .. 21 ,, 10 ,,
,, ,, ,, brown heart plus alcoholic poisoning .. .. 47 ,, 76 ,,

In A–2 it is probable that the figures for brown heart include a small amount of internal cork which could not be distinguished with certainty.

* Mean concentration for last four weeks only, owing to earlier leakage.

† The figures for B, C in the A–1 series are probably reversed but the fact cannot be traced.

JONATHAN A, 1935.

A–1—Picked 7 March. Stored 8 March. Ex Store 2 May. Cut 31 May.

Lot.	Mean % CO_2.	% Sound.	% Brown Heart.	% Breakdown.
A	2·9	100	..	..
B	5·5	100	..	..
C–2	5	100	..	..
C–1	8	100	..	..
E–1	10·8	100	..	..
D	14·2	100	..	..
E–2	16	100	..	..
Control	0–1	100	..	..

A–2—Picked 1 April. Stored 3 April. Ex Store 29 May. Cut 4 June.

Lot.	Mean % CO_2.	% Sound.	% Brown Heart.	% Breakdown.
A	2·8	100	..	..
B	5·8	100	..	..
C	8·4	100	..	..
D	13·7	88	8	8
E–2	14·4	64	32	16
E–1	18	32	68	8
Control	0–1	100	..	..

Owing apparently to depressed respiration the CO_2 content could not be maintained at the desired concentration in several instances, notably in A–1. See letterpress.

A–2 Percentage wastage due to	brown heart only	69
,, ,, ,,	breakdown only	9
,, ,, ,,	brown heart plus breakdown	22

JONATHAN B, 1935.

Picked 16 April. Stored 18 April.

Lot.	Days in Store.	Days over 15% CO_2.	Final % CO_2.	% Sound.	% Brown Heart.	% Breakdown.	% B/H & B/d.
V	98	1	15·1	56	8	36	..
Y	98	4	15·6	40	8	56	4
X	65	20	20·5	76	20	12	8
Z	98	44	22·6	8	52	92	52
W	91	35	24·5	12	52	88	52

Percentage wastage due to	brown heart only	8
,, ,, ,,	breakdown only	54
,, ,, ,,	brown heart plus breakdown	38

Discussion.

On the data obtained from the three varieties used, French Crab was the most, and Jonathan the least, susceptible to both brown heart and alcoholic poisoning. Indeed, Jonathan gave no evidence of susceptibility to the latter. Liability to both increased with the carbon

dioxide concentration. The association with maturity is not clear, but injury apparently increased with maturity in French Crab and Jonathan, but not in Sturmer.

Sturmer A in 1934 had apparently a lower susceptibility to brown heart and a higher susceptibility to alcoholic poisoning than in 1935. Sturmer B, though less susceptible to low temperature breakdown in 1933 than Sturmer A, was apparently more susceptible to brown heart and less to alcoholic poisoning than A in 1935.

Low temperature breakdown appeared only in Jonathan. It increased with the maturity at picking time, the carbon dioxide concentration, and the length of storage. It is therefore probable that similar results would be obtained with French Crab and Sturmer in years when susceptibility to breakdown is higher than it was in 1934 and 1935.

Slight injury occurred in French Crab with a concentration of carbon dioxide of under 3 per cent., and under 6 per cent. in Sturmer, but none occurred at concentrations under 8 per cent. in Jonathan.

Delay in ripening, as shown by the ground colour, occurred with all concentrations over 1 per cent. carbon dioxide. This effect increased up to about 5 per cent., but apparently did not increase at still higher concentrations.

On the whole, the best out-turn in respect to ground colour and freedom from injury was from concentrations of 2 to 3 per cent. It would therefore appear that in a year like 1935 the desirable concentration of carbon dioxide was 2 per cent. for a mixed loading of Tasmanian apples in refrigerated holds in which the temperature would be in the region of 32°F.

The apparent low susceptibility of Jonathan to carbon dioxide injury suggests that it would be a suitable variety for gas storage experiments, particularly as it is generally regarded as having only a short storage life in Tasmania.

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The Chemistry of Australian-Grown Tobacco.

Observations made during a Preliminary Investigation, carried out from 5th June, 1934, to 30th June, 1935.

By N. F. B. Hall, M.Sc., and J. C. Earl, D.Sc., Ph.D.†*

It has been recognized for some time that, in order to arrive at definite facts concerning the aroma and smoking quality of Australian-grown tobaccos, chemical investigations are necessary, but it was not until the Commonwealth grant mentioned below was made available that a suitable opportunity was presented to engage in such work.

Early in the year 1934, Mr. G. D. Ross, Under-Secretary of the New South Wales Department of Agriculture, discussed with Professor Earl of the University of Sydney the possibility of his (Professor Earl) carrying out certain investigations with a view to determining *inter alia* (*a*) the difference between tobacco leaf with a good aroma and tobacco leaf having a bad aroma, and (*b*) whether any treatment of the objectionable leaf would improve it.

Mr. Ross also discussed the matter with the Council and it was finally arranged, on Professor Earl agreeing to supervise the work, to carry out the investigations under the aegis of the Council. Mr. Ross also undertook to furnish the funds involved in the work by providing the Council with a portion of his departmental allocation of the Commonwealth's grant of £20,000 per annum to the various State Departments of Agriculture and to the Council for tobacco work (see this Journal 7: 120, 1934). The article that follows is a brief account of the progress that has been made in the work in question.—Ed.

I. Introduction.

Much chemical work on tobacco is being carried out in various parts of the world, notably in the United States, Russia, and Germany, but attention in those countries is being directed to problems rather different from those which face us in Australia. The workers overseas are concerned with the chemical differences, usually delicate in character, which occur in tobaccos of accepted smoking quality, while we have to consider the nature of the chemical constituents which make some Australian leaf bad or useless as smoking tobacco.

The plan of investigation which is being followed in attacking our problem falls into three main sections—

(1) To discover and define the constituents of tobacco smoke which may be classified as objectionable on the one hand or as desirable on the other in the various types of tobacco, namely, cigar, cigarette, pipe, &c. As a development of this aspect, an effort should be made to correlate the substances found in the smoke with specific properties, such as aroma, flavour, effect on the throat, and so on.

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(2) To investigate the substances in the tobacco leaf which give rise to the various identifiable constituents of the smoke, and to study their decomposition in relation to the conditions of smoking.

(3) To search for methods of controlling the composition of the finished product such as by modifying conditions of growth, varying the curing process, and by treating the leaf during ageing and manufacture.

As a preliminary to putting such plan into effect, a familiarity with the various chemical substances to be encountered and with the methods of detecting and quantitatively estimating them, is obviously necessary. Few of the standard methods of analysis can be used for tobacco without special modifications adapting them for the purpose. Much of the early work had thus to be directed to devising suitable analytical methods.

2. The Composition of Tobacco Smoke.

A complete chemical analysis of a tobacco smoke would be very difficult. There are, however, certain constituents of the smoke which have a major influence on its properties, and these are probably to be classified in two groups, namely—

(1) Substances imparting characteristic pleasant or objectionable aroma or taste; for example, various resins and essential oils, pyridine, amines, sulphur compounds, &c.

(2) Substances producing other physiological effects on the smoker, either desirable or otherwise, for example, nicotine, ammonia, carbon monoxide, methanol.

For a proper comparison of a range of tobacco in respect of their smokes, it is necessary to burn them under standard conditions. It is not easy to standardize the conditions of burning because such factors as the moisture content of the tobacco, the condensation of tar on the unburnt portions, and so on, have to be taken into account.

The present investigation was commenced by comparing the smokes produced from tobaccos which had been classified as "good" and "bad" after the usual smoking tests. The bad tobaccos gave unpleasant odours suggestive of the lower amines and also a larger amount of tar than the good tobaccos. The most clearly demonstrable difference was that the smoke from good tobaccos was slightly acid or neutral, while that from bad tobaccos was usually definitely alkaline. Measurement of the degree of alkalinity showed that, in general, the lower the tobaccos had been classified in the smoking tests, the more alkaline was the smoke they produced on burning. What was measured was, of course, the excess of alkaline over acid constituents in the smoke, and the results might be interpreted as showing a deficiency of acid or an excess of alkali. Since the alkaline substances contain nitrogen, and must be derived from the breaking down of nitrogenous constituents of the tobacco, it might be expected that a tobacco containing much nitrogen would be the most likely to give an alkaline smoke. The results obtained in the preliminary work show this to be generally the case, and it may be assumed as a working hypothesis that high nitrogen content corresponds with low

quality. This will be true only if the high nitrogen content is not compensated by a high content of acidic substances as is sometimes the case in overseas tobaccos, but in the Australian samples so far examined no such compensation has been observed. The nitrogen content of a good light tobacco is about 1.0 to 1.5 per cent. (of dry solids), that of the best samples 2.0 to 2.5 per cent., and that of the very bad Australian-grown samples 3.0 to 4.5 per cent. The presence of organic acids in the leaf and the production of acids during combustion tend to control the liberation of nitrogen bases by holding them combined as salts, and it is a well-known fact that the addition of acids to a bad tobacco often improves the smoke.

3. Chemical Analysis of the Leaf.

The nitrogenous constituents of the leaf may be of several different types, so that a closer analysis than the simple estimation of nitrogen is necessary. American and European workers have followed the distribution of the nitrogen in the leaf among many different types of combination, and their methods have given a basis for the work on Australian tobaccos. On the range of samples so far examined, the correlation of the distribution of the nitrogen among the various types of nitrogen compounds with the quality of the leaf is not definite, but it is possible that further work in this direction may lead to interesting conclusions.

Whereas some, at any rate, of the nitrogen-containing substances in the leaf are responsible for the appearance of objectionable constituents in the smoke, it appears that the organic acids, carbohydrates, and "resins" have a beneficial influence. As already mentioned, they control the alkalinity of the smoke either by their initial acid character or by the acidic nature of their combustion products, but they may also improve the aroma and flavour in other ways in conjunction with the essential oil and waxes present. The estimation of organic acids in tobacco is important, and will be applied to the Australian samples under examination when the technique has been mastered and the necessary equipment obtained.

In American tobaccos, the common organic acids (citric, malic, and oxalic) constitute about 7 to 12 per cent. of the total solids of the leaf, and resins from 5 to 7 per cent. The sugars vary from an almost negligible quantity in heavy cigar leaf to about 10 per cent. in flue-cured cigarette leaf.

4. Methods of Controlling the Composition of the Leaf.

(i) *Control on the Plant.*—The general conclusion has been reached by numerous plant physiologists, working on material from many sources, that in the later stages in the life of plant leaves there are very definite changes in nitrogen content. In many plants it has been shown that the yellowing of the leaves in autumn is accompanied by a sharp fall in the amount of nitrogen they contain. During the past season an attempt was made to trace a similar change in tobacco. It was found that there was a marked steady drop of nitrogen from 4.6 per cent. (of dry solids) in half-grown leaves to about 2.0 per cent. in leaves which had been allowed to yellow on the plant. The effects of

topping, suckering, and allowing to flower were studied, but it appeared that these operations had not a great enough influence to be detected by the somewhat approximate methods of examination used.

More detailed analyses, not yet complete, show that there is an extensive degradation of protein substances into water-soluble materials during the maturing of the leaves on the plant. In half-grown leaves the amount of nitrogen combined as insoluble proteins was 3.5 per cent. of the dry solids (or 75 per cent. of the total nitrogen present); in leaves which had yellowed on the plant the nitrogen combined as insoluble proteins had fallen to 1.0 per cent. (or 40 per cent. of the total nitrogen present). It is apparent that the migration of the nitrogen from the leaf must be via the midrib to the stem. This is important, because it has been shown that, although there is a similar breaking down of protein substances during the curing processes, the degradation products have no means of exit from the leaf, and the total nitrogen changes very little during curing. Therefore, harvesting too early anchors an excessive amount of nitrogenous substances in the leaf, and although they may be changed during curing, they are not removed.

(ii) *Control during Curing.*—Investigation of the changes occurring in the chemical composition of the leaf during flue-curing is still proceeding. The results coincide generally with those recorded by American workers. Up to the present the following conclusions have been reached—

(*a*) Under normal conditions about 25 per cent. of the total solids orginally present disappear during curing.

(*b*) Little of the nitrogen, if any, is eliminated, so that the percentage of nitrogen in the total solids increases in a corresponding degree.

(*c*) An extensive degradation of protein substance occurs. It is not yet established whether the degradation follows exactly the same lines as that occurring when the leaf is allowed to ripen on the plant.

A great deal more work on the chemical changes occurring during flue-curing is indicated, and plans are being made for an intensive investigation during next season.

Thrips Investigation.

7. On the Effect of Temperature and Food upon Egg Production and the Length of Adult Life of *Thrips imaginis* Bagnall.

*By H. G. Andrewartha, M.Agr.Sc.**

(*From the School of Agriculture, University of Melbourne.*)

The work described in the following article forms part of the programme of investigations on thrips which are being carried out as a co-operative enterprise between the Thrips Investigation League, the Council for Scientific and Industrial Research, the Waite Agricultural Research Institute of the University of Adelaide, the University of Melbourne, and other bodies. Through the helpful co-operation of the University of Melbourne, laboratory accommodation and other facilities have been generously made available at the University's School of Agriculture, in connexion with the investigations in Victoria (see this *Journal* 6: 216, 1933). The article discusses work centred at that School.—Ed.

Summary.

The insects used in these experiments were all taken from various generations of the same laboratory colony. Temperature and food were the variables. The humidity was maintained uniform at a S.D. of 5 mms. throughout.

It was found that no eggs were laid below about 8.5°C. At higher temperatures, the total number of eggs laid was not affected by temperature, but the rate of egg-production was proportional to the temperature.

The insects lived for a much longer period at the low than at the higher temperatures: the mean length of life of females at 23°C. was 45.7 days compared with 251.3 days at 8°C. Males lived as long as females at 8°C., but had shorter life at 23°C. (males 31.5 days, females 45.7 days).

Food was found to play an important part in the production of eggs. Without pollen, egg production did not proceed normally. Probably it is the protein content of the pollen which makes it so necessary. The stamen of *Antirrhinum* (with the anther removed) contained sufficient protein to support life, but not sufficient to enable normal egg production to proceed. When the leaf tissue of *Plantago lanceolata* or *Trifolium repens* was the only food available, the length of life was reduced and no eggs were produced.

1. Introduction.

A study of the seasonal fluctuations in the numbers of *Thrips imaginis* in Victoria (Andrewartha and Steele, 1934) and in South Australia (Evans, 1933, 1934, and 1935) has shewn that there is a definite seasonal rhythm. Normally, the population is at a very low level during the late summer and the winter; there is a relatively small increase in the autumn and a very large one in the spring. The three environmental factors of major importance in regulating these fluctuations are temperature, food, and soil moisture. The direct effect of soil moisture on the insect has already been discussed* (Evans 1934, Andrewartha 1934). The present paper is concerned only with the effect of temperature and food upon the production of eggs and the length of life of adults.

* An officer of the Council accommodated at the School of Agriculture, University of Melbourne.

* Indirectly, it is of importance, since it influences the insects through their food. Without adequate soil moisture in the autumn, there is a dearth of food. Early autumn rains are also of importance in that they result in the early flowering in the spring of certain annuals, notably Cape weed (*Cryptostemma calendulaceum*).

2. Description of the Experiment.

The thrips for these tests were taken from different generations of a standard laboratory colony (Andrewartha 1934). They were reared at 23°C. on rosebuds from which the petals had been removed. When they were ready to pupate, they were placed singly in small glass phials (3.5 cms. by 0.7 cms.) loosely stoppered with cotton wool, and then removed to the temperature at which they were subsequently to spend their adult life. During the experiment they were handled as little as possible. If one escaped during the process of changing its food, it was picked up on a dry camel hair brush and returned to its tube. Nevertheless, casualties occurred. All the tests (except that at 8° C. where 15 were used) were commenced with 20 adult females. Losses during manipulation usually reduced these to about 15 or 16 by the end of the experiment.

In those cases where temperature was the variable, the food consisted of one snapdragon (*Antirrhinum*) stamen with the anther adhering, which was renewed every day at 23° C., 20° C., and 16° C., every second day at 12.5° C., and once per week at 8° C. The stamen which was removed each day from the tube was examined for eggs, by mounting it in modified De Faure's fluid† (Steele 1935); when the stamen was heated for a few seconds in this fluid and the cover slip applied with a gentle pressure, the eggs could be counted quite easily under a binocular.

The temperatures employed were controlled within an extreme range of ±1°C. They were all obtained with the multiple temperature incubator described by Andrewartha and Andrewartha (1935), except the highest (23° C.), for which a Hearson parasite incubator was used. The humidity of the incubator compartments was controlled by the use of saturated solutions of appropriate salts. These were adjusted to give a saturation deficiency of 5mm. at each temperature. The air inside the small tubes containing the thrips was probably always moister than this owing to the presence of the food. The saturation deficiency was kept uniform rather than the relative humidity, since the former would give uniform evaporation and the latter would not (Buxton 1931, Gunn 1933).

3. Presentation of the Data.

The results have been grouped into tables according to whether temperature or food was the variable factor. Thus Table 3 deals with the effect of temperature upon egg production and the length of life of females; Tables 5 and 6 deal with the influence of food upon these two phenomena. In addition, Table 4 compares the length of life of females with males, Table 1 shows the rate of egg-laying, and Table 2 the duration of the pre-oviposition period. The data of Table 3 have been treated statistically to determine (*a*) whether the total number of eggs produced at the various temperatures differ significantly from each other, and (*b*) whether the rate of egg production could be considered to have linear relationship to temperature. These analyses are summarized in Tables 3_A and 3_B respectively.

The results have also been presented graphically. In Figure 1, the cumulative totals have been plotted against time; the eggs laid each day

† By far the greater part of this work was done by A. Mills. He also prepared the illustrations.

were added to the previous total to obtain each successive point on the curve. In Figure 2, a theoretical straight line has been fitted to the data by calculating the regression coefficient for "eggs per day" on "temperature." The observed points have been plotted as well, for comparison with the theoretical line.

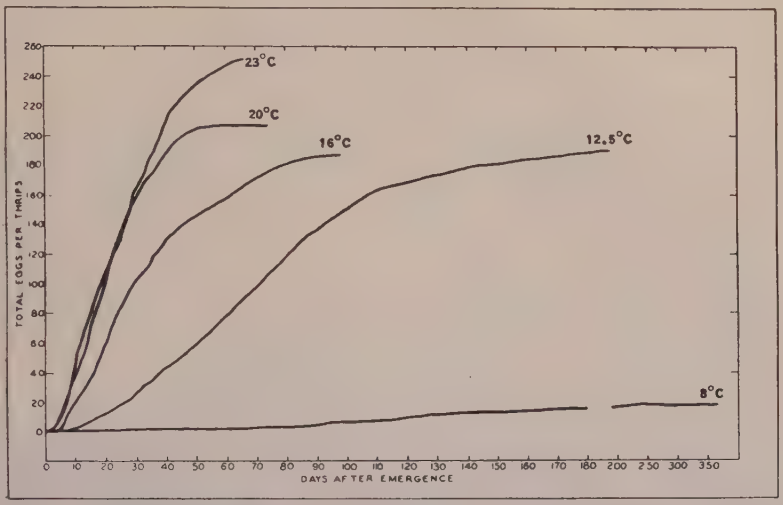

FIG. 1.—Showing the influence of temperature upon egg-production and length of life of females of *T. imaginis*. Each line represents the progressive total of eggs laid plotted against the number of days after emergence.

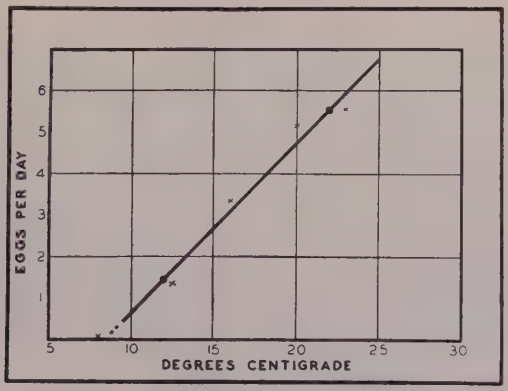

FIG 2.—Showing the influence of temperature upon the rate of egg-production by females of *T imaginis*.

4. Discussion of the Results.

(*a*) *Egg-laying Habits.*

Thrips imaginis normally embeds its eggs in the tissues of the stamens, petals, sepals, or leaves of its host plant. Under the conditions of this experiment, eggs were laid readily in the stamen of *Antirrhinum*, the leaf of *Trifolium repens*, and the leaf of *Plantago lanceolata*, but it was very rare to find an egg in the anther of

Antirrhinum. After the final pupal ecdysis, there followed a pre-oviposition period, which varied from 2.53 days at 23° C. to 10.25 days at 12.5° C. If we consider that egg-laying occurs only at temperatures above 8.5°C. (see Figure 2), the pre-oviposition period consists of approximately the same number of day degrees of effective temperature in each case (Table 2). *Thrips imaginis* does not lay its eggs in a series of waves or cycles. On the contrary, egg-laying is a continuous and fairly steady process throughout adult life. This is illustrated in Table 1, which shows the daily record for eight females kept at 20° C. for the first fortnight of their adult life. There was a wide variation in the performance of individual females, both with respect to the total eggs and the rate at which they were produced. This is brought out in Table 3, but it is also noticeable in Table 1, where "K" is obviously laying at a greater rate than "E." The greatest number of eggs laid by one female in 24 hours was 22; the highest total was 473.

(*b*) *The Influence of Temperature on Total Eggs.*

The thrips which were kept at 8°C. laid only an average of 18.6 eggs each. Two of them failed to lay, although they lived for 357 and 308 days respectively. The greatest number of eggs laid at this temperature was 40. It is obvious that 8°C. is about the lowest temperature at which eggs are produced by *Thrips imaginis*. At higher temperatures (see Table 3) the total eggs laid varied from 186.9 at 16° C. to 251.1 at 23°C. These differences were not significant as an analysis of variance shows (Table 3A). In this case, $Z=0.3118$, $n_1=3$, $n_2=55$. For these values of n_1 and n_2, 0.5073 lies on the .05 point of the distribution of Z, from which it follows that the above totals are not significantly different. In other words, in this experiment temperature did not affect the total number of eggs produced.

(*c*) *Temperature and the Rate of Egg-Production.*

The average number of eggs produced per day varied from 1.38 at 12.5°C. to 5.55 at 23°C. The data were tested by the method of analysis of variance to see whether the relationship between "eggs per day" and "temperature" could be expressed as a straight line. From Table 3B, it follows that $Z=0.5910$, $n_1=2$, and $n_2=55$. When $n_1=2$ and $n_2=60$, 0.5738 lies on the five per cent. point of the distribution of Z. It follows that in this case the mean variance due to deviations from regression is hardly significantly greater than the mean variance within the temperature arrays; and, consequently, a straight line can be considered to fit the data moderately well. In this connexion it should be pointed out that the mean variance within arrays (Table 3B) is itself rather large. Had the value for the mean eggs per day been fixed more exactly by using a larger number of insects, then it is possible that this method (the analysis of variance) would have brought out discrepancies in the straight line relationship which are now concealed. This theoretical line is drawn in Figure 2. It cuts the temperature axis at 8.47°C.; and this temperature is therefore the "zero of the velocity curve" for egg production in *Thrips imaginis*. It is of interest that the corresponding point for the post-embryonic development of this species was found to be 7.02°C. (Andrewartha 1935).

Peairs(1927) and Uvarov (1931) have summarized the laterature on the relationship of temperature to various physiological processes in insects. Most of the work is concerned with the rate of development

of the embryonic and the post-embryonic stages. Pearls, however, points out that other physiological processes are similarly affected, e.g., the conductivity of muscle fibre (Snyder 1908 and 1911), the rate of heart beat (Rogers 1911), and the production of carbon dioxide by insects (Krogh 1914). So it is not surprising that the production of eggs by *Thrips imaginis* should be found to fall into line with these other physiological processes.

(d) The Influence of Food upon the Number of Eggs Laid.

In every case, the addition of pollen to the diet had a very marked influence on the number of eggs produced. Nine thrips which received only the stamens of *Antirrhinum* laid an average of 19.8 eggs each; but they had an average life of 72.6 days compared with 52.1 days for the control insects, which received pollen in addition (stamen and anther) (Table 5). With the latter the addition of pollen to the ration increased the average number of eggs from 19.8 to 209.0. Those insects which received only a leaf of *Trifolium repens* lived for a relatively short time and laid practically no eggs. The same is true of those receiving a portion of a leaf of *Plantago lanceolata* (Table 6). The addition of pollen to this ration (in the form of an anther of *Antirrhinum*) prolonged life and greatly increased egg-production.

The explanation of these results probably lies in the protein content of the pollen. Apparently, neither the leaf tissue of *T. repens* nor that of *P. lanceolata* contains sufficient protein to enable *Thrips imaginis* to support life or to produce eggs.* The stamens of *Antirrhinum* (without the anthers) apparently contained sufficient protein to support life, but not enough to enable egg production to proceed normally.

(e) The Effect of Temperature upon the Length of Life.

At 23°C., females lived from 23 to 66 days; at 8°C., the length of life varied from 84 to 364 days. (See Table 3). At 12.5°C., the mean length of life of adult females was 138.6 days or slightly over 4.5 months. The prevailing temperatures for the winter months around Melbourne are lower than 12.5°C., from which it follows that, so far as the temperature of its environment is concerned, *Thrips imaginis* is capable of overwintering in the adult stage.

The relative length of life for males and females has been compared only at the two extremes of temperature. At 8°C., both sexes lived for an equal time (Table 4). At 23°C., the males had a shorter life than the females.

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* In these tests, the leaf tissue was observed to dry out slightly more than the stamen tissue, so that death may have been due, in part, to water starvation. On the other hand, eggs were laid quite freely into the leaf tissue when pollen was added. Also, in a subsequent test, where 20 adult females were kept at 20° C on the flower stems of *Plantago* whose lower ends were kept in tubes of water, they all died in less than 14 days.

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TABLE 1.—SHOWING THE RATE OF EGG-LAYING OF *T. imaginis* AT 20° C.

Thrips.	Eggs Laid on Successive Days after Emergence.													
	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
A	..	..	1	3	4	9	10	6	9	7	13	8	8	7
B	..	2	6	14	13	10	5	11	14	2	7	7	6	12
C	..	..	5	4	4	8	9	9	14	7	9	8	10	5
D	..	..	7	2	2	1	9	8	3	11	7	6	4	9
E	..	3	6	5	4	9	6	10	5	8	4	3	7	3
F	..	3	6	2	4	10	3	7	6	13	2	2	6	6
G	..	..	..	7	6	6	12	13	9	15	11	11	11	6
H	..	..	6	1	2	10	5	7	15	6	11	11	4	5
I	..	..	4	3	2	6	9	14	12	10	6	5	11	7
J	..	..	3	5	4	6	2	10	9	7	5	8	4	5
K	..	4	7	7	10	6	10	12	19	13	10	7	11	12

TABLE 2.—SHOWING THE DURATION OF THE PRE-OVIPOSITION PERIOD FOR ADULTS OF *T. imaginis*.

Temperature °C.	Pre-oviposition Period in Days.			Mean Pre-oviposition Period in Day Degrees of Effective Temperature.
	Minimum.	Maximum.	Mean.	
12·5	7	14	10·25	40·99
16	4	6	4·85	36·39
20	2	5	3·46	39·79
23	2	4	2·53	37·68

TABLE 3.—SHOWING THE EFFECT OF TEMPERATURE (WITH A SATURATION DEFICIENCY OF 5 MMS.), UPON THE EGG-PRODUCTION AND THE LENGTH OF LIFE OF FEMALES OF *T. imaginis*.

Temperature °C.	No. of Individuals.	Length of Life in Days.			Total Eggs.			Average Daily Production of Eggs.		
		Min.	Max.	Mean.	Min.	Max.	Mean.	Min.	Max.	Mean.
8 ..	10	84	364	251·3	0	40	18·6	0·0	0·19	0·08
12·5 ..	16	79	189	138·6	54	371	191·9	0·69	2·72	1·38
16 ..	13	28	98	54·9	40	324	186·9	1·29	4·49	3·39
20 ..	15	20	74	42·0	119	303	207·2	3·04	6·80	5·18
23 ..	15	23	66	45·7	116	473	251·7	3·23	7·63	5·55

TABLE 3A.

Source of Variance.	Sums of Squares.	Degrees of Freedom.	Mean Variance.
Between experiments	38,337·7	3	12779·2
Within experiments	376,776·5	55	6850·2
Total	415,114·2	58	7157·1

$$Z = \tfrac{1}{2} \log_e \frac{12779 \cdot 2}{6850 \cdot 2} = 0 \cdot 3118 \qquad n_1 = 3,\ n_2 = 55.$$

TABLE 3B.

Source of Variance.	Sums of Squares.	Degrees of Freedom.	Mean Variance.
Within arrays	70·01	55	1·273
Linear regression	162·00	1	162·00
Deviations from regression	8·30	2	4·150
Total	240·31	58	..

$$Z = \tfrac{1}{2} \log_e \frac{4 \cdot 150}{1 \cdot 273} = 0 \cdot 591 \qquad n_1 = 2,\ n_2 = 55.$$

TABLE 4.—SHOWING THE LENGTH OF LIFE OF MALES AND FEMALES OF *T. imaginis*.

Temperature °C.	Number of Individuals.		Length of Life in Days.					
			Females.			Males.		
	Females.	Males.	Min.	Max.	Mean.	Min.	Max.	Mean.
8	10	11	84	364	251·3	156	290	247·4
23	15	11	23	66	45·7	11	49	31·6

TABLE 5.—SHOWING THE EFFECT OF FOOD, WITH AND WITHOUT POLLEN, UPON THE EGG-PRODUCTION, AND THE LENGTH OF LIFE, OF FEMALES OF *T. imaginis* (AT 24° C. AND S.D.=5 MMS.).

Treatment.	Number of Individuals.	Length of Life in Days.			Total Eggs Laid.		
		Min.	Max.	Mean.	Min.	Max.	Mean.
Stamen only ..	9	56	80	72·6	0	69	19·8
Stamen + anther ..	7	26	77	52·1	104	284	209

TABLE 6.—SHOWING THE EFFECT OF FOOD (LEAF TISSUE) UPON THE EGG-PRODUCTION, AND THE LENGTH OF LIFE, OF FEMALES OF *T. imaginis* (AT 23° C. AND S.D.=5 MMS.).

Treatment.	Number of Individuals.		Mean Total Number of Eggs Laid in Twenty Days.
	Beginning.	Alive after Twenty Days.	
Leaf of *T. repens*	22	2	0·77
Leaf of *P. lanceolatus*	19	3	0·16
Leaf of *T. repens*, plus pollen ..	19	15	158·1
Leaf of *P. lanceolatus*, plus pollen ..	16	9	156·3

A Multiple-Temperature Incubator.

By H. V. Andrewartha (H. V. Steele), B.Agr.Sc., M.S. and H. G. Andrewartha, M.Agr.Sc.†*

(From the School of Agriculture, University of Melbourne.)

The work described in the following article forms part of the programme of investigations on thrips which are being carried out as a co-operative enterprise between the Thrips Investigation League, the Council for Scientific and Industrial Research, the Waite Agricultural Research Institute of the University of Adelaide, the University of Melbourne, and other bodies. Through the helpful co-operation of the University of Melbourne, laboratory accommodation and other facilities have been generously made available at the University's School of Agriculture, in connexion with the investigations in Victoria (see this *Journal* 6: 216, 1933). The article discusses work centred at that School.—Ed.

The incubator here described was devised for breeding thrips under known conditions of temperature and humidity. Our experiences with it may be of interest to others working with small insects, and the principles involved may probably be applied to an incubator suitable for larger insects. The total outlay on the construction of the incubator was about £25. Its operation involved an electric thermostat, a constant supply of water, and a supply of ice. It consumed about 24 gallons of water, 8 to 10 lb. of ice, and 2 kilowatt-hours of electricity per day.

Our original incubator was copied from MacGill.‡ It consisted essentially of a long copper tube (6 feet long, 4 inches diameter), whose two ends were maintained at different constant temperatures. One end of the tube was fitted into a tank of water maintained at 50°C., and the other into a galvanized iron box containing a mixture of ice and water (see Fig. 1A). The hot water tank was a copper cylinder holding about 6 gallons; it was insulated by successive layers of flannel and cow-hair felt. The ice box was cubical and had a content of 1 cubic foot. The two ends of the copper tube were sealed so as to keep out the water, and the inside was packed with cotton waste to prevent convection currents of air. Consequently, the flow of heat from one end of the tube to the other was obtained by conduction along the copper. The tube was insulated by a covering, about 3 inches thick, of flannel and cow-hair felt. Along its length, 10 holes were cut, each 2 inches in diameter, into each of which was fitted a glass tube 6 inches by 2 inches (see Figs. 1A and 2A, B, and C). Each glass tube formed a compartment of the incubator which was stoppered with a cork 2 inches thick. A cylindrical passage, $\frac{3}{4}$ inches in diameter, was bored down the centre of the cork; this was divided into two separate chambers by three transversely placed glass coverslips (Fig. 2A). In this way, light was allowed to enter the compartment, but loss of heat, by radiation through the window, was reduced. Humidity was regulated by the presence of a saturated

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† An officer of the Council accommodated at the School of Agriculture, University of Melbourne.

‡ *Ann. App. Biol.*, 14: 501-512, 1927.

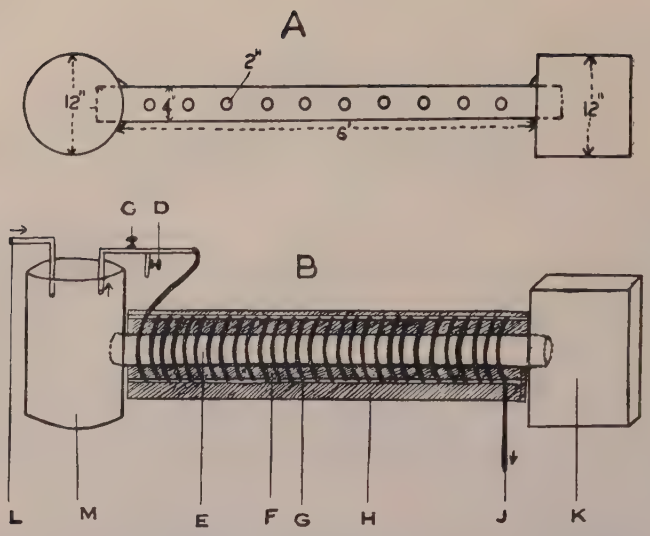

FIG. 1.—(A) Diagrammatic representation of incubator seen from above before any insulation had been added.—(B) Semi-diagrammatic representation of the fully modified incubator seen from the side. (C) outlet pipe from boiler to water jacket; (D) outlet cock for removing air from water jacket; (E) central copper tube; (F) inner insulation; (G) water jacket (hose pipe); (H) outer insulation (sawdust and cork); (J) outlet from water jacket; (K) ice box; (L) inlet to hot water tank; (M) hot water tank.

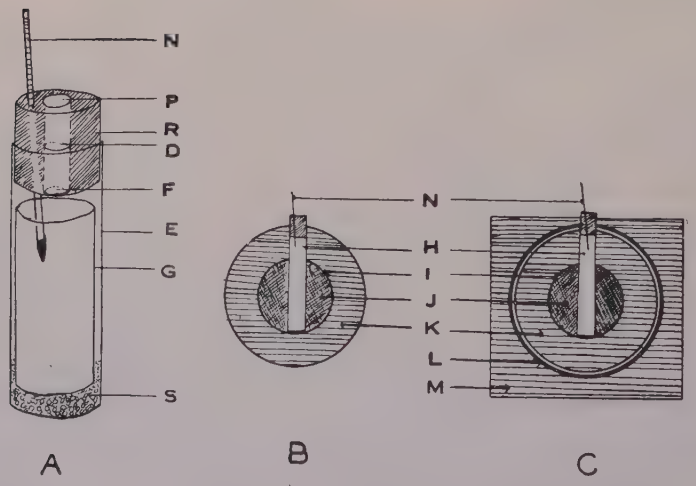

FIG. 2.—(A) A compartment of the incubator. (B) Tranverse section of incubator before modification. (C) Tranverse section of incubator after modification. (D) micro-coverslip; (E) outer glass tube; (F) micro coverslip; (G) inner glass tube to contain insects; (H) compartment of incubator; (I) central copper tube; (J) cotton waste; (K) inner insulation (flannel and cow-hair felt); (L) water jacket (hose pipe); (M) outer insulation (sawdust and cork); (N) thermometer; (P) micro-coverslip; (R) cork; (S) saturated salt solution.

solution of a suitable salt. Another tube, containing the insects, was placed inside the outer tube (Fig. 2A, G). A general view of the incubator is given in Fig. 3.

The temperature of any compartment in the incubator was determined by the interplay of two temperature gradients, one along the copper tube, the other through the lagging. At first it was thought that the steady flow of heat along the copper would compensate for fluctuations in the rate of flow of heat through the lagging, but

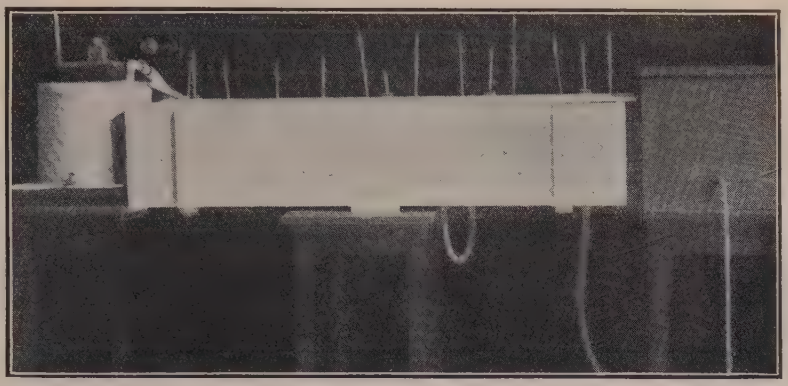

FIG. 3.—Photograph of the Incubator.

experience proved that this was not so. Table 1 shows the way in which the temperature of the room affected the temperatures in the various compartments of the incubator. The difference in room temperature between the two readings was 12.2°C. The greatest difference in the incubator compartments occurred in compartment VI.; the mean difference taking all compartments together was 7.9°C.

TABLE 1.

Date.	Temp. of Room °C.	Temp. of Water Tank °C.	Temp. of Compartments of Incubator. °C.									
			I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
1.2.34 ..	27·8	49·8	37·8	33·9	31·5	28·8	27·0	25·5	23·0	22·0	16·5	12·0
30.4.34 ..	15·6	49·8	33·2	27·1	23·1	20·1	17·5	15·4	14·1	13·0	9·5	6·4
Difference*	12·2	..	4·6	6·8	8·4	8·7	9·5	10·1	8·9	9·0	7·0	5·6

* Mean difference taking all the compartments was 7·9°C.

In order to reduce these fluctuations in temperature, a water jacket insulation, consisting of ½ inch rubber hose pipe, was wound round the incubator; the latter was then enclosed in a box packed with sawdust and sheet cork (compare Figs. 1B, 2B, and 2C). Water drawn from the hot water tank flowed through the hose pipe as shown in Fig. 1B. This was arranged by allowing water under constant pressure* to trickle into the hot water tank at L; it passed out of the tank at C, having the required temperature; the heated water passed through the hose pipe G and out at J, where it was allowed to run to

* This was maintained by a device which kept a constant level of water in a separate reservoir, giving a head of about 4 feet.

waste down a sink. The head of water was regulated to give a flow of 1 gallon per hour. With this system it was necessary to run the hot water tank at a lower temperature than with the earlier unmodified incubator; we chose 23°C.

Table 2 indicates the temperature control obtained in the compartments after the incubator had been modified as explained above.

TABLE 2.

Date.	Temp. of Room °C.	Temp. of Water Tank °C.	Temp. of Compartments of Incubator. °C.									
			I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
29.11.34	24·4	23·3	22·1	22·0	21·8	21·4	21·4	20·3	19·2	19·0	13·8	10·0
21·11·34	16·1	23·0	20·6	20·3	20·1	19·0	19·0	18·0	17·0	16·5	12·5	8·3
Difference†	8·3	0·3	1·5	1·7	1·7	2·4	2·4	2·3	2·2	2·5	1·3	1·7

† Mean difference taking all the compartments was 1·97°C.

The room fluctuated through 8.3°C., and this produced a change of 1.97°C. in the mean temperature of the incubator compartments. This represents an extreme fluctuation of a little under ± 1°C. on either side of the central temperature.

It was found that the flow of 1 gallon per hour was not enough to maintain the water jacket at a steady temperature. Indeed, the fluctuation of 1.97°C. cited in Table 2 was almost entirely due to a somewhat larger change in the temperature of the water jacket. On the other hand, it was not practicable to increase the flow, since the water flowing in at L (Fig. 1B) was cold, and that at the outlet J was allowed to run to waste. This difficulty could have been eliminated by the introduction of a pump into the system, when the water emerging at J would be pumped back to L. A more restricted range of temperatures was obtained with the modified incubator than with the original type (compare Tables 1 and 2). This could have been remedied by introducing a separate temperature control for the water jacket. The hot water tank for the incubator could then be maintained at 50°C. (as at first); and the water jacket could be kept at a lower temperature, e.g., 23°C.

These improvements would, however, add to the cost of the apparatus. The incubator, as described, functioned with us for ten months continuously, giving the degree of accuracy and range of temperatures set out in Table 2. It was necessary to observe one precaution. There was a tendency for air, driven out of solution, to accumulate in the hose pipe, thus reducing the rate of flow. To remove this air, water was driven, under pressure, through the hose for several minutes, twice weekly. This was done by closing cock C, opening cock D, and connecting the outlet tube J to the tap.

Acknowledgments.

We wish to express our very sincere thanks for the assistance rendered by Mr. A. O'Brien, of the School of Agriculture, University of Melbourne. It can truly be said that without his patient and enthusiastic help this apparatus would never have reached its ultimate form. Our thanks are also due to Mr. G. Vasey, Lecturer in Agricultural Engineering, University of Melbourne, for whose advice on several matters we are grateful.

On Some Physiological Aspects of the Phosphorus Metabolism of the Sheep.*

By Hedley R. Marston.†

Summary.

Experiments have shown that sheep fed on a diet deficient in phosphorus, even when the protein in the diet is adequate, do not develop normally. Under natural conditions, when the soil is deficient in phosphorus, the pasturage is low in phosphorus and protein, largely on account of the absence of those species of plants which contain both in adequate amounts. Under these natural conditions, the low protein intake may place a more serious strain on the animal than the low phosphorus. If the low phosphorus intake is made good by dosing the animal with inorganic phosphorus or giving it in the form of a lick, the strain on the animal may be little relieved in the absence of an adequate protein intake.

The benefit which has undoubtedly been brought about by feeding phosphorus-rich supplements to cattle grazing in some regions of the world has led many pastoralists in Australia to place phosphates in the form of licks in the paddocks in which sheep are grazing. Little attention has been given to the actual amount of phosphorus consumed by the sheep under these conditions. Reliable information on the amount of phosphorus thus consumed, and a correlation between this and the well-being of the sheep under various field conditions in Australia, is required.

The exact dietary requirements of sheep cannot be determined by a consideration of those of cattle, nor is it reasonable to expect that the smaller ruminant will react in an identical fashion with the bovine when submitted to similar grazing conditions. While it is true that sheep will benefit from a supplement of phosphorus when they are pen-fed on rations prepared from foodstuffs of extraordinarily low phosphorus content, such diets rarely have their counterpart in natural pastures. Furthermore, one may not assume that the nutritive quality of any particular pasture is primarily limited by its phosphorus content. Conventional chemical analyses of pasture clips help but little, as the material selected by the sheep is usually of very different composition from the unimproved pasture as a whole, and moreover, the proportions of other constituents of the fodder are known not only to affect the assimilation of phosphorus, but also to influence the animal's requirements of it.

The solution of the problem of the dietary requirements of sheep from a practical grazing point of view thus resolves itself into a series of carefully conducted field trials with sheep grazing on a diversity of different types of country, and the experimental work is to be extended along these lines. An endeavour has been made to bring together the experimental evidence which bears on the problems involved. The phosphorus requirements of the sheep, the factors which affect its utilization, and the symptoms of phosphorus deficiency are discussed, and the nature of the problems which occur under natural grazing conditions in Australia are briefly considered in the light of recent experimental work. It is suggested, in conclusion, that finely ground rock phosphate originating from either Christmas Island or from Curacoa Island would provide the most economic source of phosphorus if occasion should arise when the results of controlled experiments establish that such supplements bring about benefits to grazing sheep commensurate with the return from an increased production.

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* This address, which embraces an interim report of one of the activities of the Division of Animal Nutrition, was delivered at the joint discussion between the physiological and veterinary sections of the Australian and New Zealand Association for the Advancement of Science at the meeting in January, 1935.

† Division of Animal Nutrition of the Council for Scientific and Industrial Research, the laboratory of which Division is located at the University of Adelaide, South Australia.

Introduction.

It is now an established fact that the low level of available phosphorus in the soil limits the productivity of much of the Australian Continent. Hence it is not surprising to find the belief current that the growth and well-being of stock are influenced by the poverty of this element in the natural pastures, for it is fairly generally contended that pasture species reflect in their own composition the deficiency of phosphorus in the medium upon which they grow. Attempts have been, and still are being, made to combat this assumed deficiency by offering grazing sheep certain phosphorus-rich concentrates in the form of licks.

Before considering whether uncomplicated aphosphorosis is likely to be widespread in sheep living on natural pastures in Australia and whether it is probable that marked improvement in the well-being of grazing sheep in this continent may be brought about by offering mineral licks containing phosphorus, we should first review some of the physiological aspects of the phosphorus economy of this interesting ruminant.

In the course of this brief discussion I propose to outline for you some of the problems associated with aphosphorosis in sheep which have been engaging our attention in the Division of Animal Nutrition in Adelaide, and to review them in the light of the experience of other scientific workers.

The Phosphorus Retention of Growing Sheep.

Very close to 0.48 per cent. of the weight of the sheep from which the intestinal contents have been removed is elementary phosphorus (14), the major proportion, about 70 per cent. of this, being concentrated in the mineralized part of the skeleton (18). As the percentage of phosphorus in the lamb is practically identical with that of the mature sheep (14), it is evident that the call for this element by the young growing body is very nearly directly proportional to the rate of increase in weight. When skeletal development is completed and subsequent weight increase is brought about by increase of the musculature and the laying down of fat, the more or less simple relationship between weight increment and phosphorus retention breaks down, for the concentration of phosphorus in the whole flesh of the sheep is rather less than 0.15 per cent. The phosphorus retention per unit gain in weight is thus reduced at maturity to about one-third of that of the normally developing lamb. Pregnancy and lactation naturally impose an extra call for phosphorus in the ewe

The amount of phosphorus utilized by the developing animal does not however, lead us directly to the amount which should be present in the food, as the assimilation of this element is not complete, and the efficiency of its utilization is naturally influenced by many factors, some of which we shall have need to examine during this discussion.

Recourse to the literature on the requirements of the growing lamb takes us back to 1873, when Weiske (33) published the results of a series of experiments upon which have been founded the phosphorus feeding standards that are in current use. Unfortunately, the early numbers of the "Journal für Landwirtschaftlichkeit" are not available in Australia and, in consequence, we shall need to consider the figures that were tabulated by Forbes (8), who adapted them in turn from an inaugural dissertation of Wolff (35), who used Weiske's data for his calculations.

Daily Retention of Phosphorus by Sheep.

(*From Weiske's Data*).

Age of Sheep. (months.)	Live Weight. (kilos.)	Elementary Phosphorus Retained. (gms.)
5–6	23·0	0·47
7–9	30·0	0·71
10–12	36·0	1·08
13–15	38·5	1·36

It is possible that these figures have suffered in the course of publication, for it is difficult to reconcile them with more recent experience. If normal growth was proceeding, the phosphorus retention of the sheep at 13–15 months of age suggests a weight increment of at least one kilo in three days, while the data in the table imply a growth rate of less than one-tenth of this. Moreover, the reported increase in daily retention as the sheep approach maturity renders one suspicious of some error of calculation of the final figures presented in the table. Lack of precise knowledge of the nutritional history of experimental animals immediately prior to the periods over which the balance data have been collected renders it difficult to interpret most of the figures in the literature, and it would seem impossible to draw any hard and fast conclusion from them.

Kellner, in his "Die Ernährung der Landwirtschaftlichen Nutztiere" (12), computes, on the basis of Weiske's experiments with lambs 4–5 months old, that the daily retention per 50 kilos live weight is between 0.87 and 1.78 gm. of phosphorus—a gain which would imply a weight increment of between 2.4 and 5.2 per cent. of body-weight per week. In our experience, well grown Merino lambs on top-dressed natural pastures gain about 3.5 per cent. of their weight per week when about 6 months old. This would imply a retention of approximately 0.6 gm. of phosphorus per day, as their average weight at this period of growth is approximately 26 kilos.

To allow for the incomplete utilization of the phosphorus in the food, Kellner (ibid) suggested an arbitrary multiple of two to three times the quantity of phosphorus which Weiske reported was retained, and finally recommended 25 gm. of phosphoric oxide (10.8 gm. phosphorus) per 100 kilos live weight per day—a figure which is generally considered the feeding standard for this element.

Strict adherence to this standard would imply that serious aphosphorosis might be expected in 6–8 months old lambs ingesting less than 2.7 gm. of phosphorus per day, and in turn would suggest that any fodder containing less than 0.3 per cent. of phosphorus in its dry weight is deficient in this element. If this were so, the major proportion of the grazing sheep in this continent would be grossly phosphorus-deficient.

The Salivary Phosphate.

During the process of rumen digestion, the hydrolytic cleavage of cellulose by the symbiotic flora of the paunch does not simply take the course through cellobiose to d-glucose, but proceeds in a series of transformations, during which about 10 per cent. of the total energy is lost

as methane, and lactic, hydroxy-butyric, and a number of simple fatty acids are produced, but in spite of this formation of acid during digestion, the rumen contents maintain a very nearly neutral reaction (about pH 7.1) throughout life. The neutralization of the acids is accomplished through the buffer action of the alkali carbonates secreted in the parotid saliva*. With this alkali carbonate, considerable amounts of phosphorus are secreted, and it is through this cause that the paunch contents are invariably richer in this element than is the fodder before ingestion (3).

Recent investigations on the salivary secretion of sheep, carried out by Watson in the laboratory of this Division (32), indicate that the mixed saliva of the sheep usually contains between 20 and 60 mg. of elementary phosphorus per 100 ml., and that this varies with the state of phosphorus equilibrium of the animal, reaching the low level of about 10 mg. phosphorus per 100 ml. in sheep which have been for some time consuming rations poor in phosphorus, while, during periods subsequent to a generous phosphorus intake, over 100 mg. phosphorus per 100 ml. of saliva have been observed. A high degree of correlation was found to exist between the blood phosphate and the salivary phosphate.

The question whether the salivary phosphate is functional in the bacterial degradation of cellulose or in the subsequent assimilation of foodstuffs capable of being utilized for energy production, is still unsettled, but our preliminary studies suggest that neither digestion of crude fibre nor assimilation of energy is materially lessened by a phosphorus deficiency of the order of that produced by Martin and Peirce (21) in their group of experimental lambs which were receiving between 0.4 and 0.6 gm. of phosphorus each day, and whose blood phosphates were reduced to less than half of that of normal sheep.

When we consider that from 2.5 to 7.0 gm. of phosphorus enters the alimentary canal of the sheep each day through the saliva alone, and that this is materially added to by the pancreatic and intestinal secretions, it becomes evident that the efficiency of absorption of phosphorus from the intestinal tract must be of a much higher order than was suspected by the earlier investigators, for generally about five times the amount ingested in the food is poured into the rumen by the saliva and needs to be re-absorbed at lower levels of the tract if the animal is to maintain a positive phosphorus balance.

Factors which Influence the Assimilation of Phosphorus.

It is evident that the efficiency of absorption of phosphorus from the intestine is an important factor in the physiological economy of this element, and one should reasonably expect that the presence of other materials might adversely influence the solubility of phosphate in the intestinal contents and so render its assimilation more difficult.

The experiments of Marek and Wellman on young pigs (16) led them to conclude that amounts of calcium and phosphorus calculated to be adequate do not necessarily satisfy the requirements of growing

* Colin (5) computed that a grown ox secretes at least 56 litres of parotid saliva each day and through this channel Markoff (17) has estimated that between 200 and 300 gm. of alkali carbonates enter the rumen.

animals, and from his experience Marek was led to attach more importance to the relative proportions of these two elements than to the absolute quantity of either in the dietary. He represented his conception of the capacity of the alkali metals to affect the assimilation of phosphorus in an expression relating the ratio of total milligram equivalents of $CaO + MgO$ minus P_2O_5 to the dry weight of the food in grams, a relationship which he calls the "Erdalkali-Alkalizität." He considers an Erdalkali-Alkalizität of between $+20$ and $+25$ is optimum.

This view has been vigorously contested by Theiler (30), who insists that it is the absolute quantity of calcium and phosphorus in the foodstuff which determines the assimilation of these elements and that the ratio beween them has little or no influence on the absorption of either.

The marked effect that increasing concentrations of calcium ions have on the solubility of phosphate in neutral or fairly alkaline solutions is well known, and the general experience of numerous independent investigators who have studied the effects of varying the proportions of calcium, magnesium, and phosphorus ingested by rats kept under laboratory conditions on certain synthetic diets, leave no doubt whatsoever that a more or less balanced condition between these three elements in the food is essential for normal function. While the untoward effect of high calcium intake on the phosphorus balance of the lactating cow has been reported (23, 31), experiments on the large ruminants do not consistently imply untoward effects of a variation of the Erdalkali-Alkalizität beyond the limits suggested by Marek and his co-workers. The conclusion is then irresistible that the conditions under which the various observations were made must have influenced the capacity of the different experimental animals to overcome the unbalanced ratio of the alkaline earth elements and phosphorus in the rations.

Recent accessions to our knowledge of the anti-rachitic vitamin make it clear that considerable deviation from the optimal proportions of calcium and phosphorus in the food may be overcome if this accessory food factor is abundant in the dietary or if the experimental animals are brought up in an environment of strong ultra-violet irradiation, and that the further the ratio of the equivalents of calcium and phosphorus, [Ca] : [P], diverges from the optimal of between 1.0 and 2.0 the greater is the amount of the vitamin required to rectify the adverse effects (2).

During the past year, our observations on the growth, phosphorus retention, blood phosphorus, and wool production of growing sheep receiving each day 30 gm. of calcium and 10 gm. of magnesium as the carbonates, superimposed on an adequate ration, have made it clear that under the conditions of our experiment* such high amounts of alkali as to render an Erdalkali-Alkalizität of approximately 300 produced no measurable untoward effect on their well-being after 15 months, notwithstanding that extra vitamin D, which was provided to one group in the form of 5 ml. of cod liver oil per day, was excluded from the dietary. These observations provide a clue to the variation of opinion between the South African and the Central European investigators, for they suggest that under the influence of the strong sunlight met with in natural grazing in Africa and Australia the

* The experimental animals are kept individually in pens and, although shelter is provided, they spend most of their time in the open.

accessory food factor, vitamin D, is available in sufficient amount to overcome extremely wide deviations from the optimal calcium : phosphorus ratio in the pasturage. On the other hand, in Europe (especially with animals fed in barns on grain and roots) it is not unlikely that the environment and the amount of vitamin D present in the rations are not such as to ensure normal assimilation of calcium and phosphorus when the Erdalkali-Alkalizität varies appreciably from the somewhat narrow limits set down by Marek.

The conclusion that sufficient vitamin D is available under the general conditions of Australian grazing to ensure very efficient utilization of phosphorus from the natural fodders, might be drawn from our experiments.

The Symptoms of Uncomplicated Aphosphorosis.

The effects which follow a continual low intake of phosphorus in growing lambs and lambing ewes were studied in the Division of Animal Nutrition by Martin and Peirce (21). In these experiments, careful attention was paid to the constituents of the ration, and the main bulk of the protein was fed separately from the roughage in the form of a highly palatable concentrate, which was totally consumed each day by all groups. In this way, the loss of appetite which supervened after some months in those animals receiving low amounts of phosphorus did not complicate the experiment by diminishing the protein intake.

The fall in blood phosphate in the lambs consuming a diet relatively rich in protein but containing inadequate phosphorus (less than 0.6 gm. phosphorus each day) was the first abnormality noted, and this persisted. Appetite fell off in these lambs, and the total energy consumed in the roughage was reduced to about 75 per cent. of that taken by the group receiving an additional gram of phosphorus each day. The growth suffered in consequence, and during the year of observation the weight increment was only 60 per cent. of that of the controls. While the dimensions of the bones of the "low-phosphorus" animals were not significantly different from the controls, "anatomical, histological, and chemical investigation of them showed a moderate to severe degree of osteoporosis and osteomalacia, the former being more pronounced than the latter" (21). In one of the lambs bred from a ewe that was fed on phosphorus-poor rations during the major part of her pregnancy, there was some anatomical evidence of rickets and the condition was revealed on histological examination of the sternal ends of the ribs and the epiphysial junctions of the long bones. Apart from the marked pathological changes in the bones, the most striking symptom of uncomplicated aphosphorosis was the loss of appetite which supervened as soon as the readily mobilizable reserves were depleted. The reason for this loss of appetite is not clear. It seems to be, however, preceded by a fall in metabolic rate. While it is obvious that the unthrifty condition which results from aphosphorosis may be attributed to partial starvation, the reported untoward effects of aphosphorosis on wool growth (7) may also be due to lack of appetite, which, if the protein is not fed separately, will result in decreasing the amount of protein ingested to such an extent that it

no longer provides the substrate for normal wool growth. In the experiment of Martin and Peirce(21), the group receiving rations low in phosphorus but containing a good supply of protein produced as much wool as did the controls on the same ration supplemented with phosphorus, in spite of the superior growth of these controls.

The Blood Phosphate.

The phosphorus concentration of the whole blood of the normal sheep under natural grazing conditions in Australia is approximately 18 mg. phosphorus per 100 ml. (18, 32). About 25 per cent. of this exists as inorganic phosphate in which form is circulated the phosphorus which is immediately available for the various metabolic processes, and this fraction is the first to become depleted when the amount of phosphorus assimilated from the dietary is insufficient to meet the functional requirements. It has long been known that rickets in the rat, dog, and man is associated with low blood phosphate,* and Malan (15) and his associates in South Africa have demonstrated that a considerable decrease in the concentration of blood phosphate is invariably associated with aphosphorosis in cattle and sheep.

For this reason, low blood phosphate is generally considered an early diagnostic sign of phosphorus deficiency. While it has been amply confirmed that insufficient assimilation of phosphorus is followed by persistent low blood phosphate levels, diagnosis of early aphosphorosis by this means may be at times misleading, as the level of phosphate in the blood is markedly increased if the animal is either out of energy balance or is not fulfilling its protein requirements. Even in animals in complete nutritive equilibrium, the marked diurnal variation of the level of blood phosphate renders it difficult to come to any conclusion as to the state of the phsphorus balance from a single blood determination alone.

As the amount of phosphorus which is secreted each day into the rumen through the mixed saliva is, at the very least, ten times that in the whole of the circulating blood, it is not surprising that the blood phosphate level varies during the day. The phosphate concentrations in the blood of our experimental sheep which are submitted to a rigorous routine of feeding evidence marked variation. Preliminary studies by Kennedy (13)†, working in the Division's laboratories, have clearly indicated that variations from 5.0 to 3.3 mg. phosphorus per 100 ml. during the day are constantly met with in individual animals. These fluctuations might presumably be brought about by the rate of secretion of phosphorus in the saliva and its subsequent absorption from the intestine. Grazing sheep evidence a similar diurnal variation in the concentration of inorganic phosphate in their blood.

Determination of the concentration of blood phosphate of large numbers of mature sheep grazing under natural conditions have led us to conclude that "normal blood phosphate concentration" is very close to 4.5 mg. phosphorus per 100 ml., with a standard deviation of

* Or, rather, with the low product of calcium and phosphorus ions.

† Subsequently confirmed by S. W. Josland and I. W. McDonald working in the same laboratories.

approximately 0.4. Limits of variation from 3.5 to over 6.0 mg. phosphorus per 100 ml. were noted in similar sheep under identical grazing conditions.

There is little doubt that the highly vascular spongy bone acts as a buffer reservoir which maintains some degree of constancy in the blood phosphate level, but the rate of deposit and re-absorption of calcium and phosphorus from this store lags considerably behind the rapid fluctuations in the algebraic sum of the secretion and absorption of the "floating phosphate" in the intestinal tract, and so the blood phosphate varies during the process of digestion in the ruminant. Loss of this "floating phosphate" through the fluctuation of blood phosphate is prevented in the sheep by a remarkably high renal threshold, and a blood phosphate concentration of between 6 and 8 mg. phosphorus per 100 ml. of blood needs to be reached before an appreciable amount of phosphate is excreted in the urine (32). During prolonged fasting the blood phosphate level rises to above the renal threshold, and up to 1 gm. of phosphorus per day is excreted in the urine (18).

Phosphorus and Natural Grazing Conditions in Australia.

The great diversity of natural pastures which exist in Australia does not allow any extent of generalization. In both sub-tropical summer rainfall regions and winter rainfall regions, there are more or less prolonged rainless periods, when the available fodder is reduced to dry standing straw of relatively low nutritive quality.

The soils which constitute much of the grazing country are low in available phosphorus, and this influences both the extent of growth and chemical composition of the pasture species. While both the phosphorus and protein content is low in the total available fodder which develops on poor soils, these constituents are, for the greater part, translocated to the meristem tissues during development of the plants, and, in consequence, while these are still growing, a selective feeder such as the sheep suffers little or no nutritional disturbance providing the country is not overstocked. During the dry period, when growth is suspended, and much of the total nutriment has been transferred from the plants proper to the inedible seed, the phosphorus content of the pasture is very much reduced, but along with this the nitrogen is also decreased to such an extent that *the lack of protein generally becomes the limiting nutritional factor for grazing stock.* Wool production is then diminished, and growth in young animals suffers a serious setback, and may cease altogether until nutritive conditions improve. In extreme cases, during more prolonged dry periods, appetite fails, typical starvation oedema develops (19), and serious losses occur in country where there is ample roughage to provide the energy requirements of the flocks.

Symptoms exhibited by sheep grazing on country poor in phosphorus have but little in common with those of uncomplicated phosphorus deficiency produced under laboratory conditions. The lack of protein in the phosphorus-deficient pastures prevents normal animal growth, and, in consequence, the call for phosphorus is very much reduced, while the abundance of vitamin D present in the strongly irradiated pastures ensures the efficient assimilation and conservation of the phosphorus which is available. In those animals which rapidly lose

condition, the phosphorus set free from the katabolized tissues is, as a rule, sufficient to ensure a very high concentration of blood phosphorus, and so the marked pathological changes in the bones similar to those produced experimentally in phosphorus-deficient animals which consumed sufficient protein in their rations to sustain some measure of growth, are rarely met with under natural conditions. When a change is evidenced under natural grazing conditions, the bones, although light and porous, are perfectly formed, and their condition resembles that due to absolute food shortage rather than that due to uncomplicated aphosphorosis (21).

It would seem then, on *a priori* grounds, that no great benefit might be expected to follow the consumption of phosphatic supplements in the form of mineral licks by sheep grazing under natural conditions on the main pastoral areas in Australia. The great improvement obtained by Theiler and his co-workers in South Africa (30), by Henry in New South Wales (10), and by Orr and Holm in Scotland (26), by offering phosphatic supplements to cattle have not been paralleled in our experience with sheep in Australia (18, 20, 21).

The Difference in the Phosphorus Requirements of Cattle and Sheep.

The case is different with the bovine. Support of its much larger bulk calls for a more massive structure of the skeleton, and, because of their heavier frame, cattle contain close to 4.1 per cent. of ash (14), while sheep contain but 2.9 per cent., the phosphorus content of the live weight of cattle being between 0.8 and 1.1 per cent.—approximately twice that of the sheep. The growing calf, for this reason alone, needs a higher proportion of phosphorus in its food. Moreover, the amount of food consumed per unit gain (or for maintenance of body weight) of cattle is considerably less than that of sheep, for the basal energy requirements of cattle per kilo body-weight is, on account of their relatively reduced surface (surface: mass ratio), much less than that of sheep.

If, then, we suppose that cattle and sheep have equal capacities for absorption of phosphorus from the intestine, the fodder of the former must necessarily contain about three times as great a concentration of phosphorus as the dietary of the smaller ruminant if its requirements for this element are to be fulfilled during the growing period. The position is further complicated by the fact that the bovine, being very much less selective in its feeding habits, needs to ingest much of the rank, poor herbage which is generally discarded by the sheep on reasonably-stocked pastures. It is not remarkable then that cattle suffer from the ill-effects of phosphorus deficiency and develop osteomalacia and osteoporosis while grazing on country where sheep rarely, if ever, evidence such skeletal changes.

Toxic Paralysis in Sheep.

A malady affecting sheep, which resembles the series of symptoms which lead to botulism in cattle (lamsiekte), has been reported in New South Wales (28, 29), and of recent years has become so prevalent in the farming belt of Western Australia that it is now one of the major nutritional problems in the pastoral industry in the southern division

of that State. Sheep grazing on the dry standing straw of this country develop a depraved appetite that leads them to ingest carcass dèbris which, at times, is infected with the toxogenic saprophyte *Bacillus parabotulinus* (29). The attempts which are made to prevent this pica by supplying phosphatic supplements are not generally satisfactory, and it is not proven as yet that the tendency of the sheep to consume decomposing flesh, which often leads to botulism, is the result of aphosphorosis. Supplements of linseed or of oats seem to be more effective preventives of the toxic paralysis of sheep than do mineral licks containing phosphorus (1).

Albeit, phosphorus supplements are widely used in the live stock industry, and will continue to be employed until it is satisfactorily established under a diversity of field conditions that their use is not followed by improvement commensurate with the expenditure. For this reason, we might briefly inquire as to what is the most economical form of phosphorus to employ for mineral licks *if their use is indicated.*

The least costly and most readily accessible phosphatic material is finely ground natural rock phosphate. This has been objected to by veterinarians on the very real grounds that ingestion of massive amounts of certain rock phosphates is often followed by the untoward effects of chronic fluorosis, and there have been suggestions that the phosphorus is not as readily available from this material as from bone meal or the more readily soluble dicalcic and monacalcic phosphates.

Chronic Fluorosis.

Our experience in the Division of Animal Nutrition gathered, for the most part, from the experiments of my colleague, A. W. Peirce (27), indicates that ingestion of 500 mg. of fluorine per day as Florida rock phosphate plus calcium fluoride, is well tolerated for a time, but, after a lapse of about nine months, the animals consuming it cease to take an adequate amount of food, and finally refuse their rations and expire. The skeletons of mature animals so treated are characterized by chalky out-growths of the long bones and of the lower jaw. The mineralized portions of these bony excrescences have almost the theoretical composition of fluor apatite—containing 1 atom of fluorine to 5 of calcium. The permanent teeth of animals receiving fluorine are unaffected if they have erupted prior to its addition to the dietary. Young growing sheep which received 120 mg. to 140 mg. of fluorine per day have maintained normal growth for about a year, although there are some indications that untoward effects begin to develop after this time. With the exception of the first pair of incisors, the teeth of all of this group of experimental animals were of abnormal shape, the enamel was pitted, corroded, and mottled with chalky white patches, and the teeth, in consequence, appeared unglazed, and lacked their normal translucency. The growing sheep of the experimental group receiving 80 mg. of fluorine per day, have suffered no ill-effect during the first eighteen months of observation, but they are now, after two years, showing mottled enamel on the incisors recently erupted (27).

From our previous studies, it may be concluded that practically the total requirements of phosphorus of the growing lamb *under natural grazing conditions* may be met with the ingestion of about 2 gm. of

phosphorus pentoxide per day. This would imply that any concentrate having a ratio of fluorine to phosphorus pentoxide of less than 0.040 may be fed in quantities sufficient to meet all the needs of the sheep without any fear of chronic fluorosis. Such materials are accessible.

There is little doubt that the phosphoric acid of the majority of tropical island deposits originated by the leaching of the soluble phosphates from the bird guano into the underlying calcium carbonate, the phosphoric acid being originally derived from the fish ingested by the birds inhabiting the islands.

The source of the phosphate in the continental deposits is not so clearly defined, for there is abundant evidence that fish and animal remains played a part in the laying down of some, while the debris of brachiopods and other marine organisms undoubtedly contributed to the formation of others. There is satisfactory proof, however, that the high fluorine content of fossil bones and teeth, which contain up to 3 per cent. of fluorine, is the result of secondary chemical changes which have occurred over long periods. The fluorine content of the phosphate rock cannot then be attributed solely to that originally present in the bird guano or in the fish and animal remains that have played a part in the formation of the deposits. It is apparent that the fluorine in the rock phosphates, like that in fossil bones and teeth, results from long contact with fluorine-bearing waters which transform the original hydroxy and carbonate apatites into fluor apatite (25, 11, 4). The high ratio in some deposits implies that some replacement of phosphorus by fluorine has occurred, so that while the theoretical $F—P_2O_5$ ratio of fluor apatite is 0.089, this is, as a general rule, lower than that of the phosphatic rocks of continental deposits, but it is much higher than that of those of insular origin.

Figures drawn from the analyses of Jacob, Reynolds, Hill, and Marshall (11), indicate that in the relatively old continental deposits the calcium phosphate has been completely transformed into compounds containing a high proportion of fluorine, while in the comparatively young insular deposits the transformation is, as yet, incomplete. The low $F : P_2O_5$ ratio of the deposits of high grade rock from Curacoa Island and from Christmas Island, which contain 0.7 and 1.3 per cent. of fluorine respectively, support the view that these deposits are the ones which should be exploited in compounding mineral licks for stock.

The experiments in which the effects of large excess of calcium on the assimilation of phosphorus in sheep were studied strongly suggest that the phosphorus in finely-ground tricalcium phosphate is just as easily available to the sheep under natural grazing conditions in Australia as that of dicalcic or monacalcic phosphate. This contention is being put to experimental test, and in two years' time we may be able to report another chapter of these investigations.

Until further field experiments under a variety of grazing conditions are completed, we shall not be able to make any final pronouncements, but the implications to be drawn from the experimental work already completed are fairly obvious, and if we consider the available experimental evidence we should, of necessity, adopt a reserved attitude and examine the conditions very thoroughly before we uphold any policy which supports the almost universal and somewhat indiscriminate employment of phosphatic licks in the pastoral industry.

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In this short address no attempt was made to review the extensive literature on aphosphorosis, which has been extensively treated in Marek and Wellman's monograph (16) and in Sir Arnold Theiler's review (30).

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The Occurrence and Distribution of Starch in the Wood of Red Tulip Oak (*Tarrietia argyrodendron* var. *peralata*).

*By H. B. Wilson, B.Sc.**

Early in March, 1935, eleven logs from six red tulip oak trees were received at the laboratories of the Division of Forest Products for test purposes.

In red tulip oak, there is a transition zone between the sapwood and the truewood.† This zone, which is also present in some other timbers, is spoken of as the "intermediate" wood. It may be sharply defined or, in some cases, may give way gradually to the deeper colour of the truewood. In red tulip oak, "intermediate" wood usually approximates in appearance to the sapwood. The truewood is reddish in colour. The presence of this transition zone between the sapwood and truewood is of considerable interest in connexion with borer activity, especially in the case of the powder post borers. These insects confine their attack to the sapwood of those hardwoods in which it is well defined, but are stated to penetrate deeper in certain tropical timbers in which there is no sharp distinction between sapwood and truewood.

As the powder post borer, *Lyctus brunneus*, and other species of the same genus, apparently attack sapwood because of the starch it contains, and so far have not been known to cause damage in starch-free timber, a survey of the starch content of these logs was undertaken, as a preliminary to the study of borer control in this and other species.

The logs were cut between the 11th and 23rd of January, 1935, and transported to Melbourne, with the bark intact but loose in parts, and the ends coated with a waterproof composition. Wilson‡ has shown that if pieces of green ashwood (*Fraxinus* sp.), with the bark intact, are end-sealed with wax, a progressive diminution of the starch content takes place from the outer edge of the sapwood inwards. In two months, this diminution may be quite appreciable, resulting in an outer starch-free layer of wood. Nothing is known of the starch content of these red tulip oak logs at the time of felling, but it is probable that some loss of starch occurred before the tests were made at the laboratory nearly two months later.

The logs were sawn into flitches, on each end of which a test was made by planing a smooth surface and applying an N/20 solution of iodine in potassium iodide. Tree 1, which was the second smallest tree, possessed very pale-coloured wood showing no distinction between

* An officer of the Section of Timber Preservation, Division of Forest Products, C.S.I.R.

† To overcome the confusion between the terms heartwood and "heart" which latter, in Australia, is commonly applied to the central and frequently more or less decayed portion of the tree, the term *truewood* has been adopted to describe that sound portion of the tree between the sapwood and the "heart." This term is especially applicable since, while the "heart" of many Australian trees is useless, the truewood provides the bulk (and in many cases all) of the usable timber

‡ S. E. Wilson. *Annals App. Biol.* **20**: 661, 1933.

sapwood and truewood. In the other trees, a broad zone of sapwood and "intermediate" wood, 3.5 to 4.5 inches in depth, was present, and beneath this was the truewood of varying shades of red.

The results of the tests for starch may be summarized as follows.

General.

No starch was found in the truewood of the five trees in which the truewood was distinct. In the broad outer zone of light-coloured wood, the starch, where present, was in fine bands parallel with the grain. Microscopic examination of longitudinal sections of the wood showed that the cells of bands of longitudinal parenchyma were packed with starch granules, but the rays contained practically none at all. This is quite distinct from the condition in a number of other timbers which have been examined in which starch has been confined to the rays. These two types of distribution have been illustrated previously.*

Variation in Starch Content between Different Trees.

Only the butt logs will be considered, as three trees were represented by butt logs only.

The trees can be divided into two groups upon the basis of their starch content:—

(i) *Tree* 1.—In this tree, with its light-coloured wood and apparent absence of definite truewood, there was an external starch-free layer of a constant depth of one inch. Beyond this zone, the starch was found to be present for an average depth radially (measured from the outside edge of the sapwood) of 5.1 inches, with a maximum of 6.1 inches and a minimum of 4.5 inches. The butt diameter of the tree was 2 feet.

In only two observations was the starch content recorded as high as "medium." In all other cases, it fell into the "trace" and "slight" grades.†

(ii) *Trees* 2, 3, 4, 5, *and* 6.—The outer starch-free zone was prominent in trees 2 and 3, with an average depth of about 0.5 inches. In the other trees, it was narrower and frequently absent. Tree 2 was the smallest of the six, and by contrast, tree 3, though not the tallest, had the greatest girth. The average radial depths to which starch was present in the light-coloured sapwood or "intermediate" wood of trees 2, 3, 4, 5, and 6, were respectively 3.4, 3.6, 2.3, 2.7, and 2.7 inches, the butt diameter of these trees being respectively 1 ft. 6 in., 3 ft. 4 in., 2 ft. 9 in., 2 ft. 5 in., and 3 ft. 1 in. The maximum depth of 3.8 inches was recorded for tree 3.

The starch content of these trees was considerably greater than that of tree 1. "Medium" and "dense" grades were recorded frequently, half of the measurements for tree 6 falling into the "dense" grade.

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* J. E. Cummins and H. B. Wilson. This *Journal* **8**: 101, 1935.

† For further details concerning the use of these terms see J. E. Cummins and H. B. Wilson. This *Journal* **8**: 101, 1935.

Variation in Starch Content throughout the Log.

From the observations recorded, there does not appear to be any correlation between starch content and position in the log. Three logs each were cut from trees 4 and 5. In tree 4, the starch content diminished with increasing height from the butt, whereas in tree 5 it increased.

From the light colour of its wood, and the apparent absence of definite truewood, tree 1 appears to be the youngest tree. (Owing to the absence of definite growth rings, there was no reliable method for comparing the ages of the six trees.) The outer wide starch-free zone may be the result of starch depletion, during the time between felling and testing, in a zone initially containing little starch. In the other trees, in which the starch content was higher, the effects of the depletion would not be so apparent.

In no case was starch present to the full depth of the broad zone of sapwood and "intermediate" wood in trees 2, 3, 4, 5, and 6. In many of the areas tested, however, sufficient starch was present to render at least two inches of this zone susceptible to borer attack, and in some cases 3 inches. This represents a considerable portion of a matured tree, the butt diameter of which is often only 3 feet.

Foot-Rot in Sheep.

Preliminary Note on Aetiology and Possibility of Control.

*By W. I. B. Beveridge, B.V.Sc.**

The work described in the article that follows has been greatly facilitated by the Australian Pastoral Research Trust which is providing half the salary of the investigator concerned. Foot-rot, however, is but one of the problems covered by this co-operation, the main object of which is to assist the work on worms in sheep that is centred at the McMaster Laboratory.—Ed.

Summary.

The paper deals with the common type of foot-rot which, in Australia, is frequently erroneously termed "simple, non-contagious." The findings of previous workers that this is a specific, contagious disease have been confirmed by experiments.

B. necrophorus, which has been considered to be the causal organism of foot-rot by most workers, has failed in our hands to produce the disease, so it is concluded that it is not the primary causal agent.

An organism, which is described briefly, has been found in great numbers in active lesions, and there is some evidence suggesting that it is the causal agent, although confirmation of this is lacking pending its isolation. This organism presents some difficulty in classification, but is probably an unusual type of spirochaete.

The recent work of Marsh and Tunnicliff, showing that the causal agent of foot-rot does not live very long in dry soil, when considered in the light of the epidemiology of the disease in most of the affected districts in Australia, suggests that the infection must be carried by the sheep during periods when the disease is in abeyance. The infection has been observed to persist as a superficial skin lesion in the interdigital space for as long as three months during the summer. In certain districts the infection may also be carried over from season to season by more obviously infected sheep.

The possibility is raised of eliminating foot-rot from flocks and infection from properties by removing or treating all cases of latent and chronic infection during periods when the disease is in abeyance.

1. Introduction.

The description in the literature of two or more "types" of foot-rot has led to some confusion, for the description and nomenclature of these "types" often differ, and it appears to be questionable whether they are different diseases or merely different clinical manifestations of the same disease. It is necessary, therefore, to indicate at the outset that the disease discussed in this paper is that characterized by separation of the horn from the soft tissues followed by a certain amount of necrosis. This is by far the most prevalent "type" in this country, and the descriptions and illustrations of Marsh and Tunnicliff (1934) leave no doubt that it is identical with the common form of foot-rot in the United States of America.

Murnane (1934), Marsh and Tunnicliff, and Dr. H. R. Carne of this Laboratory (unpublished experiment) have demonstrated conclusively that this disease cannot be set up merely by maceration of the sheep's feet in water when there is no source of specific infection, as was believed in some quarters. It has been thought by some that the disease is produced by pus burrowing between the horn and sensitive laminae and can be caused by any pyogenic bacteria gaining entrance. To determine whether this is possible, the writer set up infections with

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pyogenic bacteria by deeply scarifying the skin and adjacent soft horn in the interdigital space and applying cultures (see Expts. 4, 5, and 6—Table I.). Pus formed and under-ran the horn from the horn-skin junction to the edge of the sole, but in all cases this infection cleared up spontaneously without foot-rot developing. Where foot-rot has been set up, the clinical appearance is quite different. The horn merely separates from the sensitive laminae, commencing at the horn-skin junction between the digits, and at first very little or no pus is to be seen. A few days later, a small amount of thin pus and necrotic material is present, and later more extensive tissue necrosis develops, leading in all cases to a long-standing infection.

Mohler and Washburn (1905), Hasenkamp (1909), Murnane, and Marsh and Tunnicliff, have all found that foot-rot is a specific contagious disease; this finding is confirmed by the writer's experiments. These workers isolated *Bacillus necrophorus* from foot-rot lesions, and considered it to be the specific causal organism. However, experiments on the reproduction of the disease with this organism have not given uniformly positive results. Mohler and Washburn, Hasenkamp, and Murnane claim to have produced foot-rot with pure cultures, while Marsh and Tunnicliff were unable to do so. But Murnane did not obtain consistent results with cultures in his experiments, and in Mohler and Washburn's experiments the lesions produced with pure cultures healed spontaneously, which is unusual for foot-rot and rather resembles the lesions produced in this Laboratory with pyogenic bacteria similarly applied.

2. Experimental Reproduction of Foot-Rot.

The writer has isolated *B. necrophorus* from seven cases of the disease, but has been unable to reproduce the disease with this organism. Experiments on the reproduction of the disease were conducted in the following manner and the results are summarized in Table I. In all cases, the skin and portion of the horn of the posterior half of the interdigital space were deeply scarified before applying the material to be tested. Scarification and application of material were usually carried out on two successive days. Except in Expts. 8 and 15, not more than two feet were treated on each sheep. Experimental sheep were kept in separate pens with concrete floors, strict precautions being taken to avoid accidental transmission of infection. The need for this care is shown by the results of Expt. 15. Possibly, the readiness with which foot-rot is contracted by accidental transmission may account for the claims of certain workers that they reproduced the disease with pure cultures. Expts. 8 to 11 were carried out starting with the same material obtained from a recently developed case.

In all, 22 feet were treated with *B. necrophorus* without producing foot-rot, whereas 26 feet directly infected with material from foot-rot lesions, or indirectly merely by contact, all developed the disease. Some of the *B. necrophorus* strains used had been recently isolated from foot-rot lesions by cultural methods, without having recourse to rabbit inoculation. Pus produced by subcutaneous injection into sheep of *B. necrophorus* cultures and a combination of *B. necrophorus* with a virulent pyogenic organism also gave negative results. *B. necrophorus* usually set up a slight infection under the horn where it could be demonstrated in the pus. But in all cases these lesions healed spontaneously without foot-rot developing, and a similar effect was obtained with cultures of *Staphylococcus aureus* and of a pyogenic corynebacterium.

TABLE I.—EXPERIMENTAL REPRODUCTION OF FOOT-ROT.

Experiment No.	Nature of Material Applied After Scarification.	Number of Feet Treated.	Result.
1	Necrotic material from cases of foot-rot ..	13	All developed foot-rot
2	Pure culture of *B. necrophorus* isolated from naturally occurring foot-rot	10	No foot-rot developed
3	Pus produced by subcutaneous inoculation of pure culture of *B. necrophorus* in a sheep	4	,, ,, ,,
4	Culture of *Staphylococcus aureus*	3	,, ,, ,,
5	Culture of pyogenic corynebacterium isolated from foot-rot	2	,, ,, ,,
6	Culture of pyogenic corynebacterium isolated from foot-rot + culture of *B. necrophorus*	2	,, ,, ,,
7	Culture of *B. necrophorus* + anaerobic cocci isolated from foot-rot	2	,, ,, ,,
8	Culture-mixture of organisms isolated from foot-rot (other than *B. necrophorus*)	3	,, ,, ,,
9	Mixed primary culture sown directly from foot-rot lesion	4	All developed foot-rot
10	Filtrate (L3) of culture used in Experiment 9	2	No foot-rot developed
11	Filtrate (L3) of culture used in Experiment 9 + culture of *B. necrophorus*	2	,, ,, ,,
12	Supernatant fluid from centrifuged emulsion of material from foot-rot lesions	4	,, ,, ,,
13	Supernatant fluid from centrifuged emulsion of material from foot-rot lesions + culture of *B. necrophorus*	2	,, ,, ,,
14	Emulsion used in Experiments 12 and 13 not centrifuged (controls)	3	All developed foot-rot
	Scarification with no Application.		
15	In contact with cases of foot-rot in concrete-floored pen	10	All developed foot-rot
16	Controls in separate pen	6	No foot-rot developed

It is submitted that the only interpretation that can be placed on the results of these experiments is that *B. necrophorus* is not the primary causal organism of foot-rot in sheep. In the writer's opinion, the results of Marsh and Tunnicliff's experiments also indicate that *B. necrophorus* is not the cause of foot-rot, although these workers conclude that it is "the primary infective agent, but that there is another factor involved which we have been unable to discover". However, the fact that this organism has been found by a number of workers to be almost constantly present in lesions cannot be lightly disregarded, and it is possible that its presence is a necessary factor in the development of foot-rot.

3. Search for Causal Agent.

On perusal of Table I., it will be seen that necrotic material taken from foot-rot lesions (Expts. 1 and 14) and first generation mixed culture of this material in cooked heart medium (Expt. 9) contained the specific infection, which was also transmitted by contact (Expt 15). Mohler and Washburn were also able to reproduce the disease with mixed cultures of foot-rot material. A further search was therefore made for the causal organism.

Ludovic and Blaizot (1928), Howarth (1930), and Blot and Lammarre (1932), describe as the cause of foot-rot (owing to its prevalence in lesions) a spirochaete which the first named authors called *Treponema podovis*. These workers all describe a spirochaete with the regular spirals characteristic of the Treponemata. Only rarely have organisms of this description been found in foot-rot lesions in this Laboratory. This is in accord with the findings of Murnane, who could find such organisms in only two or three cases, and of Marsh and Tunnicliff, who made a careful and extensive search for spirochaetes with negative results. Howarth (1934) more recently considers that *B. necrophorus* has been incriminated as the causal organism.

A number of different bacteria were isolated from foot-rot lesions, but under experimental conditions all failed to produce the disease (Expts. 4, 5, 6, and 8). L3 filtrates of mixed foot-rot culture gave negative results (Expts. 10 and 11); Murnane's attempt to produce the disease with a filtrate also failed. In Expts. 12, 13, and 14, further evidence was obtained against the possibility of a filterable virus being the cause. Material was taken from foot-rot lesions, emulsified in broth, and centrifuged at 3,500 revolutions for 40 minutes. The supernatant fluid was non-infective although the uncentrifuged emulsion was infective. This experiment was conducted twice.

At this stage, the experiments indicated that foot-rot is caused by a specific organism which, however, is neither a filterable virus, nor a spirochaete, nor a bacterium cultivable by ordinary means.

Histological examination of numerous foot-rot lesions showed in all cases filaments resembling *B. necrophorus,* though many were rather more tenuous and curved, penetrating further into the tissue than other bacteria (see Fig. 1). Examination of smears taken from early lesions showed numerous filaments, the majority of which were not typical of *B. necrophorus* in that they were thinner and sometimes more sharply curved. At first, these were all thought to be *B. necrophorus*, because, when attempts were made at isolation, both by cultural methods and animal inoculation, only *B. necrophorus* was found. However, subsequent examinations have shown these finer filaments to be a separate organism. Attempts to isolate this organism have so far been unsuccessful, and thorough systematic study of it has not yet been possible; for the sake of convenience, it will be referred to as the X organism in this paper.

4. The X Organism.

Until this organism has been isolated, it is not possible to determine definitely whether it is the cause of foot-rot, but the following evidence places it under strong suspicion:—

(i) It has been found in all cases of foot-rot in which it has been looked for, and is present in great numbers in active lesions near the healthy tissue. On the other hand, it could not be found in the transitory lesions produced by scarification of the interdigital space of three sheep not infected with foot-rot, which indicates that it is probably not a common non-specific invader.

(ii) Histological examination of foot-rot lesions permits of only three interpretations of the cause of foot-rot:—(*a*) *B. necrophorus*, (*b*) an ultravisable virus, and (*c*) the

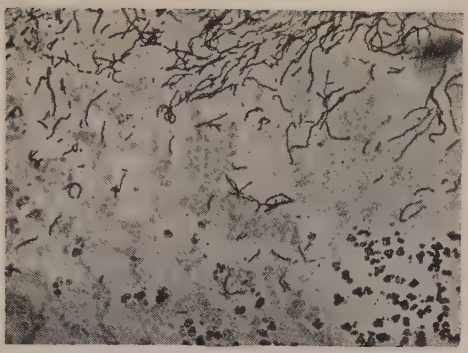
X organism. *B. necrophorus* by itself has now been eliminated as a probability, and there is experimental evidence against a virus being the cause.

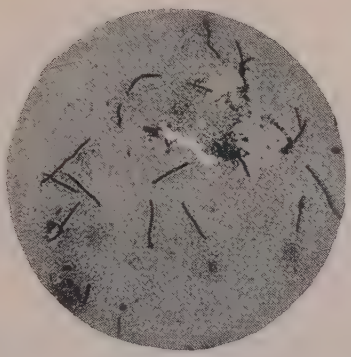
(iii) The results of the experiments on the reproduction of the disease given earlier in this paper do not in any way conflict with the supposition that X is the cause. First generation mixed cultures sown directly from foot-rot, which have been shown to be infective, sometimes show the X organism in smears, although it is usually difficult to demonstrate owing to overgrowth with other bacteria.

(iv) In tests on the viability of the infective agent of foot-rot described below, the X organism had died (as judged by loss of motility and poor staining) when the material in the test had lost its power to produce foot-rot.

The X organism is Gram-negative, and the most suitable stain for demonstrating it in smears is aniline gentian violet. It is a filamentous organism in which neither branching nor spore formation have been observed. The sides are parallel, though there may be slight tapering at the ends which, however, are rounded and never pointed. Its dimensions when stained with aniline dyes or in Congo red preparations, are usually 0.25 to 0.3μ wide by 6 to 10μ long, but may vary from 0.20 to 0.35μ wide by 5 to 25μ in length. In silver preparations, the width is about doubled (which makes the organism more difficult to distinguish from *B. necrophorus*). The axis of the filaments in smears varies according to the method of preparation, so is best observed by dark ground illumination, when the organism appears as a single line of light (owing to its fineness), and is seen to be motile and flexible. The filaments are most often straight, but may show curving, which is usually only slight and in one direction. They possess a peculiar type of motility. Straight elements usually progress in a slow even manner without showing any flexion, unless they come in contact with an obstacle, when they usually bend, and may curve around it or reverse their direction. They sometimes perform slightly undulatory movements as they progress, and the end sometimes moves to and fro as though feeling. Occasional individuals actively flex the body into a semi-circle and then straighten out again or curve in the opposite direction. In smears made by mixing material with a drop of fluid on the slide and fixing while wet with osmic acid vapour, the organism is usually straight or only slightly curved, but occasional elements show several more or less regular waves. However, when smears are made by spreading the material on the slide without moistening it and drying before fixing, most filaments are irregularly curved and many bend sharply, giving various twisted forms. A granular stage has been observed in several preparations stained by concentrated carbol-fuchsin, and in some dark ground preparations in which the organisms had lost their motility and were presumably dead. Two microphotographs of smears of the organism are shown in Figs. 2 and 3.

Material containing this organism has been inoculated by various routes into sheep, rabbits, guinea-pigs, mice, and a pig, without the organism becoming established in the tissues (except, of course, in the tissues of the foot of sheep), so that it is apparently of low pathogenicity.





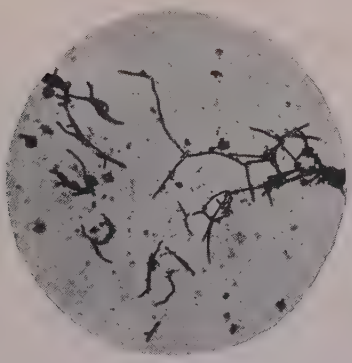


Fig. 1 (*top*).—Section of foot-rot lesion. (Dobell's modification of Levaditi's silver impregnation. × 300.)

Fig. 2 (*centre*).—The X organism in smear. (Fontana-Tribondeau. × 700.)

Fig. 3 (*bottom*).—The X organism in smear. (Zetnow's silver method. × 440.)

From the description of the organism given above, it is not possible to determine whether it is a spirochaete or bacterium. The only valid criterion for differentiating between bacteria and spirochaetes seems to be that the latter move without flagella, progress being made by rotatory action around their long axis. X organisms from lesions, washed and stained by Zetnow's method, have shown no flagella (or terminal filaments), although these were well demonstrated on contaminating bacteria. A careful study of the motility of the organism by dark ground illumination gives one the impression that it rotates, although it has not yet been possible to ascertain this with certainty. This suggests that the organism is a spirochaete. Its dimensions, the difficulty of cultivating it artificially, and the occasional occurrence in smears and sections of definitely wavy forms, all support this view, although the fact that spirals are not seen in living organisms examined by dark ground, indicates that, if it is a spirochaete, it is an unusual type.

It might be argued that the X organism is not likely to be the cause of foot-rot, because it has not been recorded by previous workers. However, it is not improbable that they did observe it. Some may not have distinguished it from *B. necrophorus* owing to it somewhat resembling that organism in smears from lesions, and because in subsequent cultural and animal inoculation experiments, only *B. necrophorus* could be detected. Indeed, in Figs. 3, 5, and 6, Plate I., in Mohler and Washburn's paper, there are shown some slender filaments closely resembling the X organism. On the other hand, it may probably be the organism which other workers have described as a typical spirochaete with regular spirals, although such a description is not justified for the X organism. Only on two or three occasions have typical Treponemata, such as these workers described, been seen in preparations from foot-rot lesions in this Laboratory.

Attempts are now being made to isolate the organism in order to test its aetiological significance, and study it more fully. As yet, it has not been possible to cultivate it.

5. Possibility of Controlling the Disease.

Since foot-rot has been conclusively demonstrated to be a specific contagious disease, it should be controllable by wiping out the infection. Year after year, in many districts, the clinical manifestation of the disease disappears from the flock during the summer, or for longer periods, and then recurs when conditions are favorable. During the periods when the disease is not apparent, the causal agent must persist either in the soil or in the sheep, for re-introduction of infection can be excluded in many instances.

Recent investigations in America, by Marsh and Tunnicliff, showed that the infection did not live in the soil of pens after 15 days when it was allowed to dry, or after 30 days when kept continually wet. In a swamp, the infection apparently persisted in an attenuated form from one year to the next, but heavily infected irrigated pasture rapidly lost its infectivity when allowed to dry. In this Laboratory, on two occasions, material was taken from foot-rot lesions, tested on sheep to prove its power to produce the disease, and then kept moist in a Petri dish on the bench for seven days. On both occasions, when tested on sheep after this period, the material was found to have lost its power to produce foot-rot.

Although confirmation of these findings is required under various field conditions in Australia, it is probable that during the summer, when the disease is in abeyance, the infective agent persists in the animal, and the following observations suggest how this may occur.

Several sheep, which had apparently recovered from foot-rot, i.e., the hooves had become normal, were turned out during the summer on to short pasture which was dry, except for occasional rains. When examined a week later, the skin in the posterior portion of the interdigital space of some feet which had been affected was depilated, slightly moist, and inflamed. The sheep were not lame as the lesions were very superficial, and there was no separation of the adjacent horn from the sensitive laminae. Smears from the inflamed skin showed *B. necrophorus* (which was demonstrated by inoculation into a rabbit), and large numbers of the X organism described above. The lesions persisted for from two to three months while the sheep were running on dry pasture. After this time, some developed into typical cases of foot-rot, and others cleared up.

Thus it would appear that during periods when there are no obvious cases of foot-rot in a flock, the infection may live in superficial lesions in the feet of some of the sheep, ready to spread throughout the flock when conditions are again favorable. Apart from these latent infections, in certain districts there are always a few members of the flocks affected with more apparent chronic lesions in the hoof, in which the infection would live throughout the summer. Chronic lesions in the hoof have persisted for over 18 months in experimental animals kept for most of the time in pens with dry concrete floors, and material from these lesions has readily produced the disease when applied to other sheep.

The elimination of foot-rot from flocks and infection from properties by treating or removing all cases of latent and chronic infection during dry summers while the disease is in abeyance, presents an attractive possibility which is being investigated.

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Wheat Variety Investigations: Progress Report.

1. Experiments at Canberra, Wagga, Merredin, and Adelaide in 1934.*

By J. R. A. McMillan, M.S.†

The work reported in the subjoined is the result of co-operative effort between C.S.I.R. (Division of Plant Industry), the Departments of Agriculture of New South Wales and Western Australia, and the Waite Agricultural Research Institute. The experiments were planned by officers of the Division of Plant Industry, Miss F. E. Allan,‡ Messrs. H. F. Smith,§ C. S. Christian,§ K. Loftus Hills,§ and S. G. Gray,¶ and the writer, in consultation with the Director of Plant Breeding, Mr. H. Wenholz, of the N.S.W. Department of Agriculture. The Departments of Agriculture of N.S.W. and Western Australia provided land properly prepared and fertilized, and office and laboratory accommodation at Wagga and Merredin respectively. The former Department also made student labour available when necessary, and provided most of the seed. The remainder was supplied by C.S.I.R. and the W.A. Department of Agriculture. At Adelaide, all facilities were provided by, and the experiment was conducted entirely by, the Waite Agricultural Research Institute under the supervision of Dr. I. F. Phipps. The actual work at Canberra, Wagga, and Merredin was performed by officers of the C.S.I.R.

To all co-operating organizations and individuals mentioned, the thanks of the Council are cordially tendered.—Ed.

In most plant breeding programmes, yield is such an important character that it must always be taken into consideration. A knowledge of its mode of inheritance or that of the characters determining it would greatly facilitate the planning of crosses and the production of improved types. But yield, being an end product of growth, is so complex that the common methods of analytical genetics are inadequate to investigate its inheritance. It therefore seems desirable to define the more important plant characters determining yield, and then to investigate the inheritance of these separately. In order that data for the first part of such an analysis might be obtained, variety experiments were initiated in 1934 at Canberra (F.C.T.), Wagga (N.S.W.), Merredin (W.A.), and Adelaide (S.A.). The experiments at all places were identical, so that the only differences between them were environmental (soil, climate, and dates of seeding consequent upon climatic conditions). As these were conducted mainly for the purpose of inter-variety comparisons, it was desirable to include as many varieties as possible in order to sample most types. Taking into consideration the labour available, data to be collected, and magnitude of error aimed at, it was found possible to include about 100 varieties.

Methods.—The land used was typical of the wheat land of the district, was prepared according to local methods, and was fertilized with superphosphate at the rate of 1 cwt. per acre by means of a wheat drill.

The experiments were arranged in 8 x 8 Latin Squares, with a check variety (Nabawa) common to all. The varieties were classified into two groups, the later ones being sown in squares 1–8 and the earlier ones in squares 9–16, with the exception that squares 4 and 12 were duplicates containing some early and some late varieties. As stated previously, the arrangement was similar at all stations.

* Complete data are not published on account of expense. They will be made available on request.

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Each plot consisted of five rows 4 feet long and 4 inches apart. Seeds were sown 2 inches deep and 2 inches apart with a Woodfield dibber. This represents a seeding rate of approximately 75 lb. per acre, which was somewhat higher than usual to conform with the proposal put forward by Hudson and Stafford,* and by the Committee of the American Society of Agronomy for Standardization of Field Experiments.† Of each plot, only the central 2 feet of the three central rows, representing an area of 2 square feet, were used for test purposes. Ample borders were provided between pathways and test plots.

For each variety, the seed used at all four locations was drawn from the same sample.

A test of this technique against drill-sown plots conducted by Dr. I. F. Phipps, at Adelaide, gave satisfactorily similar results with regard to both actual and relative yields. The results are shown in Table 1.

TABLE 1.—COMPARISON OF YIELDS OF DRILL-SOWN AND SMALL DIBBED PLOTS AT THE WAITE INSTITUTE, ADELAIDE.*

Material.	Bushels per Acre.	
	Drill Plots.	Dibbed Plots.
	(Sown 21st May, 1934.)	(Sown 22nd May, 1934.)
Gluyas x Minister	50·02	46·73
Sepoy 324J	45·50	42·78
Gluyas x Unknown	43·60	42·58
Nabawa x Hard Federation	41·42	42·38
Ford x Hard Federation	40·13	42·75
Nabawa (W.I. 33–2)	38·90	41·53
Sepoy (Rust Resistant Seln.)	38·00	41·38
Nabawa (W.V.E.)	..	46·60
	(Sown 16th July, 1934.)	(Sown 19th July, 1934.)
Early Sepoy Seln.	48·00	50·45
Canberra x Gluyas	33·66	50·00
Nabawa (W.V.E.)	..	44·18
	(Sown 16th July, 1934.)	(Sown 19th July, 1934.)
Sepoy 324J	51·57	48·98
Nabawa x Hard Federation	49·70	45·43
Sepoy (Rust Resistant Seln.)	44·19	44·65
Ford x Hard Federation	44·03	42·83
Gluyas x Minister	41·47	44·55
Nabawa (W.I. 33–2)	40·51	41·35
Nabawa (W.V.E.)	..	40·95

* Conducted by Dr. I. F. Phipps.

Data.—Table 2 contains a list of the varieties used, together with their yields in bushels per acre for each station. The standard error of variety means for most squares have been included.

Other data, including seasonal notes, number of plants per plot, number of ears per plant, number of grains per ear, average weight per grain, number of tillers per plant, weight of sheaf, incidence and amount of various diseases, dates of various growth periods, &c., were recorded, but owing to expense they are not published here. Mimeographed copies of these will be made available by the writer to any one interested.

* Hudson, A. W. & Stafford, W. C. The rate of seeding of wheat in relation to variety trials. *Emp. Journ. Expt. Agric.* **2**: 29-39, 1934.

† Report of the Committee for Standardization of Field Experiments. *Journ. Amer. Soc. of Agron.* **25**: 803-828, 1933.

Table 2.

Sq.	Variety.		Yield in Bushels Per Acre at—			
			Canberra.	Wagga.	Merredin.	Waite Inst.
I.	Nabawa	C.S.[1]	45·0	51·0		49·2
	Zealand Blue	..	49·8	37·0		43·9
	Ford	..	49·7	58·7		46·5
	Yandilla King	..	48·3	40·8		48·1
	Sands	..	48·1	41·8		41·7
	Dan	..	46·1	48·2		39·9
	Minister	..	44·3	24·2		45·2
	Albit	..	18·5	..		27·1
		S.E.[2]	..	2·83	..	3·06
II.	Nabawa	C.S.	43·9	33·8		46·5
	Baringa	..	58·7	33·7		59·2
	Forel	..	56·5	30·0		44·8
	Dart's Imperial	..	54·5	21·1		47·1
	Duchess	..	44·6	26·2		50·3
	Kenya XB c6040	..	38·3	28·8		47·6
	Galgalos	..	38·0	...		43·1
	Ghurka	..	37·2	23·9		46·4
		S.E.	3·49	2·33		2·74
III.	Nabawa	C.S.	47·4	32·3		40·1
	Exquisite	..	55·4	27·0		41·5
	Major	..	47·9	22·6		41·2
	Calare	..	47·1	27·1		37·3
	Cadia	..	42·5	25·6		36·1
	Sepoy	..	37·9	21·3		40·6
	Jonathan	..	32·7	20·8		35·3
	Marquis	..	31·6	20·2		31·6
		S.E.	2·11	1·51		2·30
IV.	Nabawa	C.S.	46·2	32·9		40·2
	Dundee	..	56·3	37·6		49·4
	Bordan	..	54·6	36·4		41·8
	Free Gallipoli	C.S.	50·3	27·2	Data	38·5
	Cleveland	C.S.	40·5	28·3	rejected[4]	37·0
	Ranee[3]	..	38·6	32·7		46·8
	Comeback	C.S.	35·3	32·8		40·8
	Early Bird	C.S.	30·1	31·7		36·2
		S.E.	3·50	2·23		2·26
V.	Nabawa	C.S.	49·4	36·1		36·3
	Rajah	..	49·5	38·6		47·7
	Apollo	..	47·6	36·8		34·2
	Penny	..	41·7	28·9		40·2
	Zealand	..	36·1	22·9		37·5
	Stockman	..	34·4	24·8		40·6
	Hope	..	32·9	24·9		32·5
	Currawa	..	28·1	31·2		42·0
		S.E.	2·83	2·20		2·56
VI.	Nabawa	C.S.	45·1	46·3		42·1
	Morley	..	60·3	42·4		51·7
	Turvey	..	55·3	33·7		43·7
	Numba	..	49·3	36·2		54·5
	Canimbla	..	47·1	30·5		45·2
	Marshall's No. 3	..	46·3	32·6		45·7
	Genoa	..	34·4	24·0		35·1
	Preston	..	33·7	25·4		32·9
		S.E.	2·86	3·08		2·35
VII.	Nabawa	C.S.	44·4	30·3		48·9
	Mallan	..	63·0	36·4		..
	Graham	..	53·9	36·9		48·4
	Sutton	M.S.[1]	49·8	30·7		41·1
	Grune Dame	..	47·1	22·9		..
	M.26 (Nab. x Carrabin) ..	M.S.	46·1	33·2		36·1
	Wandilla	..	43·0	28·7		43·4
	Horneblende	..	22·3	15·6		..
	Early Sepoy	..	..	..		46·2
	Free Gallipoli	..	..	..		38·1
	Cleveland	..	..	..		35·5
		S.E.	2·67	3·02		2·32

[1] C.S. and M.S. mean Canberra and Merredin seed respectively.
[2] Standard Error of variety means.
[3] Ranee 4H used at the Waite Institute.
[4] Data rejected from Merredin Squares 1–8 because of poor and delayed germination on account of dry weather.

TABLE 2—*continued.*

Sq.	Variety.		Yield in Bushels Per Acre at—			
			Canberra.	Wagga.	Merredin.	Waite Inst.
VIII.	Nabawa	C.S.	Not sown	32·6	Data rejected[1]	41·5
	Cleveland	..		27·9		..
	Free Gallipoli	..		26·8		..
	Marquillo	..		26·2		..
	Peragis	..		24·8		..
	Heine's Kolbern ..	..		22·0		..
	Ridit	..		16·2		..
	Berkley Rock	..		15·3		..
	Gluyas x Minister ..	..		..		46·7
	Nabawa 33–2	..		..		46·6
	Nabawa x Hd. Federation ..	..		..		42·8
	G. Nat. Hybrid	..		..		42·6
	Ford x Hard Federation ..	..		..		42·4
	Sepoy 324 J	..		..		42·1
	Sepoy R.R. ..	..		..		41·4
		S.E.		1·52		2·23
IX.	Nabawa	C.S.	54·3	19·9	22·0	42·2
	Waratah	..	53·1	27·6	21·4	41·7
	Quality	..	46·9	19·2	17·4	39·4
	Bunyip	..	39·0	24·0	18·3	37·5
	Aussie	..	38·1	25·6	24·0	42·0
	Firbank	..	35·9	21·1	16·6	33·7
	Pusa 80–5	..	33·7	24·3	14·9	40·7
	Garnet	..	31·4	15·1	14·6	35·6
		S.E.	3·24	1·59	1·19	1·58
X.	Nabawa	C.S.	52·4	21·7	20·9	45·9
	Sultan	..	50·9	21·7	22·7	47·7
	Gluyas Early ..	..	50·5	24·1	23·0	43·8
	Canberra	..	49·0	24·3	22·2	51·0
	Riverina	..	46·9	28·1	23·6	45·4
	Caliph	..	43·5	21·7	23·5	48·5
	Improved Steinwedel ..	..	42·3	26·4	16·5	35·3
	S. H. J.	..	33·9	23·9	18·3	41·2
		S.E.	2·21	1·83	1·95	1·55
XI.	Nabawa	C.S.	49·3	25·6	23·7	43·1
	Gluclub	..	54·9	28·5	22·8	50·1
	Geeralying	..	52·8	32·6	29·9	37·8
	W 785 Y	..	51·8	29·9	19·8	38·2
	Minflor	..	49·8	30·9	20·7	40·1
	Baroota Wonder ..	..	44·7	21·4	21·2	39·8
	Carlisle	..	43·9	31·9	29·2	48·6
	Kenya XB c6042 ..	..	41·8	27·6	21·4	40·8
		S.E.	2·33	1·77	1·89	2·70
XII.	Nabawa	C.S.	50·7	30·5	Not sown	42·1
	Bordan	..	54·9	31·6		45·2
	Ranee	..	47·0	28·5		47·3
	Early Bird	C.S.	45·1	33·9		45·1
	Dundee	..	44·9	27·9		46·4
	Cleveland	C.S.	32·4	27·3		39·2
	Comeback	C.S.	31·5	24·0		33·3
	Free Gallipoli	C.S.	29·1	20·3		40·9
		S.E.	2·35	1·54		2·75
XIII.	Nabawa	C.S.	51·5	25·4	27·8	43·0
	Garra	..	48·3	29·8	28·2	49·0
	Cowhort	..	47·2	25·9	22·7	44·5
	Minflos	..	44·8	29·1	21·9	40·4
	Gresley	..	42·2	30·0	21·4	37·9
	Bobin	..	41·9	24·7	27·8	49·7
	Rajah	..	36·4	17·3	27·0	48·5
	Federation	..	36·1	16·7	20·4	39·8
		S.E.	2·44	1·75	1·50	1·04
XIV.	Nabawa	C.S.	50·3	30·5	31·3	41·0
	Bencubbin	M.S.	53·1	26·9	30·7	46·6
	Clarendon	..	45·8	30·6	24·6	30·9
	Merredin	M.S.	41·0	29·8	29·6	42·8
	Gular	..	39·6	35·5	32·9	42·6
	Carrabin	M.S.	30·4	26·6	22·9	41·5
	M. 35	M.S.	27·4	25·6	25·3	34·3
	Noongaar	M.S.	25·9	27·0	32·6	33·6
		S.E.	2·88	2·53	1·42	3·03

[1] Data rejected from Merredin Squares 1–8 because of poor and delayed germination on account of dry weather.

TABLE 2—*continued.*

Sq.	Variety.		Yield in Bushels Per Acre at—			
			Canberra.	Wagga.	Merredin.	Waite Inst.
XV.	Nabawa	C.S.	Not sown	24·3	24·9	41·2
	Gluyas Early	M.S.		28·0	27·2	45·7
	Totadgin	M.S.		26·6	29·7	45·9
	Pusa 113	..		23·9	16·8	..
	Bald Early	..		23·8	17·8	..
	S. H. J.	M.S.		21·5	16·4	41·3
	Bena	..		18·8	20·6	..
	Cedar	..		17·1	18·6	..
	Early Sepoy Selection ..	..		..	..	50·5
	Can. x Gluyas	..		..	..	50·0
	Nabawa C. 6679 ..	..		..	..	44·4
	Ford x Hard Federation ..	..		..	..	44·0
		S.E.		1·68	1·25	1·66
XVI.	Nabawa	C.S.	Not sown	26·9	Not sown	41·0
	Early Bird	..		31·1		..
	Kenya XB c6041 ..	..		28·0		..
	Nabawa	..		27·2		..
	Florence	..		26·2		..
	Carrabin	..		24·8		..
	Pusa 111	..		23·8		..
	Comeback	..		22·1		..
	Gluyas Nat. Hybrid ..	..		..		49·2
	Sepoy 324 J.	..		..		49·0
	Nabawa x Hd. Fed. ..	..		..		45·4
	Sepoy R.R.	..		..		44·7
	Gluyas x Minister ..	..		..		44·6
	Ford x Hard Federation ..	..		..		42·8
	Nabawa 33–2	..		..		41·4
		S.E.		1·72		1·59

NOTES.

Fisheries Investigations now in Progress by the Council.

In 1909 the Commonwealth Government initiated an investigation of occurrences of demersal or "bottom-dwelling" fish—for example, flathead—in Australian waters. The steam trawler *Endeavour* was built in Australia for the exploration, which ended tragically with the loss of the vessel and all hands in 1914.

The investigation established the existence of two large trawlable areas giving promise of profitable commercial fishing. One extended southwards within the 100-fathom line from near Port Stephens, on the New South Wales coast, to east of Flinders Island, in Bass Strait. This area is now the base of a trawling fleet operating from Sydney. The other area extends for several hundreds of miles within the 100-fathom line of the Great Australian Bight; its commercial development has been retarded by its distance from large consuming centres.

With the loss of the investigation vessel and the outbreak of the World War, this valuable exploratory work ceased. However, interest in the potential value of Australia's marine resources did not flag, and a considerable amount of attention was given to the whole subject by the former Development and Migration Commission. The Commission was largely instrumental in the holding of a national fisheries conference of representatives of the Commonwealth and State Governments, and of others interested in fisheries, which met in Sydney in 1929, and which urged, in view of the great national advantages to be derived from a fuller utilization of Australia's fisheries resources, the setting up by the Federal Government of an organization for the scientific, statistical, and practical investigation of fisheries.

Financial conditions were largely responsible for delays, but, some years later, detailed consideration to the lines along which work might appropriately be undertaken was given in a report prepared at the Government's request by Sir George Julius (Chairman of C.S.I.R.), Professor W. J. Dakin (University of Sydney), and the Hon. J. Gunn and Mr. S. Fowler (Development Branch, Prime Minister's Department). The Development Branch (which took over many of the activities of the former Development and Migration Commission) also continued to collect information and reports, and generally to prepare the way for the investigations that are now being put in hand.

Finally, in May, 1935, the Commonwealth Government decided to provide a sum of £20,000 for the financial year 1935-36 and £15,000 per annum for the ensuing four years for fisheries research and investigation; in July, 1935, it also decided to place general responsibility for the work directly upon C.S.I.R. At the same time the Government also arranged to make Mr. S. Fowler's services available to the Council, to the staff of which he is now attached as Fisheries Officer.

The Council is now considering the most appropriate arrangements it can make for the whole work. In this consideration the attention that others have given to the matter in the past is proving particularly helpful. It has been decided to invite tenders for the construction of the necessary vessel, the plans for which are practically complete. The boat, which will be essentially a practical fishing craft, will be similar

to the type so successfully used in North America for the capture of pelagic fish—such as pilchards or sardines and salmon. It will also be equipped to do a certain amount of fishing for demersal fish. The steel hull will be 80 feet in length, and will be fitted with a Diesel engine. A small laboratory will be installed, as well as electric depth-sounding and wireless apparatus.

Steps will be taken at an early date to secure the services of a fisherman experienced in the use of the special fishing nets, such as the purse-seine, which have not previously been used in Australian waters.

Another decision that has been reached is to appoint a Junior Marine Biologist to collate the existing scientific information concerning Australian fisheries and generally to give due attention to the scientific aspects of the work of the experimental vessel. The Council has been assisted in its consideration of the programme of this appointee by a report on possible marine biological investigations submitted by Professor W. J. Dakin, of the University of Sydney. Professor Dakin has also undertaken to assist the Council in its fisheries programme by acting in the capacity of a consultant.

Finally, appropriate attention will be given to the utilization side of the fisheries problem. Thus the Council's Section of Food Preservation and Transport will assist by supervising work on the preservation of fish by freezing, curing, and canning. Other avenues of utilization provided by fish meals, fish oils, and other by-products will also be studied. The Officer-in-Charge of the Section (Dr. J. R. Vickery) and Professor Dakin have already furnished the Council with a joint report on some of these matters.

Co-operative Investigations into Mastitis in Dairy Cows.

A commencement has recently been made in Victoria with the co-operative investigations into mastitis in dairy cows rendered possible by the provision of funds by the Australian Dairy Cattle Research Association and by the co-operation of various bodies. A brief account of the present position of the work and the events that led up to its initiation is given in the paragraphs that follow.

Two of the most important problems with which the Australian dairying industry is faced are contagious abortion and mastitis. Estimates of the annual losses caused by mastitis in other countries offer convincing evidence that it is one of the most serious scourges of the dairying industry all over the world. In Germany the annual loss is approximately £10,000,000, and in the United States of America a recent estimate, based on a dairy cow population of roughly 22,000,000, is that mastitis costs over £14,000,000 per annum. Naturally, an enormous amount of research work has already been carried out all over the world in an endeavour to control the disease. The extent of this work and the amount of the losses still caused by the disease are evidence in support of the views (i) that as yet no adequate means of prevention or cure have been found; and (ii) that a long and carefully-planned programme of research work is necessary before an effective method of control will be developed.

The Australian Dairy Cattle Research Association is a body that has been set up by the dairying industry with the principal objects of fostering Australian investigations into contagious abortion and mastitis. Funds were obtained by contributions from various sources, and a year

or so back the Association made arrangements for work on contagious abortion to be carried out at the Glenfield Research Station of the New South Wales Department of Agriculture under the direction of Dr. H. R. Seddon, Director of the Station. The funds devoted to that work are of the order of £1,500 per annum.

Subsequently, the Association obtained further funds, and at the present time its main contributions are the following:—£2,000 per annum for two years by the Commonwealth Bank (from its Rural Credits Development Fund), £2,000 per annum for five years by the Australian Dairy Council, £1,000 per annum for five years by the Commonwealth Government, and £500 per annum for five years by the Victorian State Government.

In consequence, in July, 1935, the Association was able to see its way clear to provide £3,750 per annum for mastitis work over a period of years. The C.S.I.R. was then asked to undertake the investigations in association with the Victorian Department of Agriculture and the Veterinary Research Institute of the University of Melbourne. The Council agreed, and the following arrangements have been made for the control of the work. The Chief of the Council's Divisions of Animal Health and Animal Nutrition (Dr. L. B. Bull) will be in charge of the investigations; but, while he will be directly responsible to the Executive Committee of C.S.I.R., he will be made a member of the Victorian Sub-committee of the Association, so that he may maintain close touch with its members, to whom reports will be presented from time to time. In addition, the Chief Veterinary Officer of the Victorian Department of Agriculture (Mr. R. J. De C. Talbot) and the Director of the Veterinary Research Institute of the University of Melbourne (Dr. H. E. Albiston) will be associated with Dr. Bull in the direction of the investigational work.

About 350 acres* of a property known as "Road's End," and situated in the neighbourhood of Berwick, some 30 miles from Melbourne, have been leased for a period of years. This property already has a number of improvements on it, and they require little alteration for the investigators' special purposes. The main activities at Berwick will be directed in the first instance towards establishing a clean herd, the objects of such action being (i) to provide facilities for the detailed study of clean animals; (ii) to provide clean animals for introduction into affected herds for purposes of observation; and (iii) to determine whether the disease can develop in a clean herd apart from the introduction of infected cows. In other words, the work at "Road's End" will consist, broadly, of a study of the normal cow from the point of view of its acquiring mastitis.

The disease is also to be studied as its exists in selected dairy herds in localities around Melbourne. The bacteriological work involved will be largely centred at the Veterinary Research Institute of the University of Melbourne.

Division of Forest Products—Its new Laboratories and Equipment.

It has previously been intimated that the Commonwealth Government has allocated £25,000 (from loan funds allocated to the relief of unemployment) for the erection of central laboratories for the Council's Division of Forest Products, and that following this decision Mr. Russell Grimwade has made the Council a gift of £5,000 towards the cost of new equipment for the Division.

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* 250 of these consist of pasture.

Some progress has now been made in connexion with the laboratories and the equipment. The buildings will be located on an area of about 1 acre situated in Yarra Bank-road, South Melbourne, and close to the south end of the Spencer-street bridge. The site is being provided by the Victorian State Government for a nominal rental. It is adjacent to the timber wharves of Melbourne and is in the centre of a number of wood-working industries.

Plans for the buildings were completed some time ago, and a tender for their erection has now been accepted. The main laboratory will comprise a three-story, rectangular, steel-framed, brick-faced building, about 180 x 53 feet in plan, with provision for the addition of a fourth story later.

The basement will be used as a store for the Division's collection of authenticated timber samples, &c. The first floor will be given over to administrative offices, computing and draughting, seasoning and utilization offices, and to a library and lecture-room. The second floor will accommodate chemical, preservative, timber physics, and wood anatomy laboratories, together with the museum and photographic section. Single-story buildings in the rear of the main building will house experimental seasoning kilns, wood-working equipment, testing machines, &c. Incidentally, one of these buildings—the timber mechanics' laboratory—will exemplify the use of new wood connectors in building construction, that particular laboratory requiring a central tower to accommodate the large timber-testing machine mentioned below.

The new equipment rendered possible as a result of Mr. Grimwade's gift will comprise a sawmilling plant, a large timber-testing machine, and possibly a veneer plant. The timber-testing machine—a Southwark-Emery type—has already been ordered; it will be capable of applying loads up to 600,000 lb., and will take columns up to 24 feet in length and beams or built-up structures such as bridge girders of practically unlimited length. It will be hydraulically driven, the load being indicated on sensitive dial gauges which enable increments of load as low as 20 lb. to be accurately measured. It will extend about 30 feet above the ground, besides requiring a pit about 12 feet deep to take the loading mechanism. One of the considerations that prompted the purchase of this machine was in order that the new methods of timber construction which are coming into fairly wide use overseas might be investigated from the point of view of their use under Australian conditions. It thus becomes necessary to test not only individual parts of structures such as joints, but also to carry out fairly large-scale tests on completed structures.

Codling Moth Investigations.

At a meeting of the Standing Committee on Agriculture (formerly a body of C.S.I.R., but now a body of the Australian Agricultural Council) which met in Melbourne in September, 1934, some attention was given to the codling moth problem. As one result, it was resolved that a Committee, representative of the State Departments of Agriculture and of C.S.I.R., should be formed to survey the position and to make recommendations for the co-ordination and further development of codling moth research work. (The State Departments of Agriculture are carrying out this work; C.S.I.R. has not concerned itself with codling moth investigations beyond investigating the possibilities of the insect parasite, *Trichogramma*, some years ago.)

The formation of this suggested Committee was subsequently approved by the Australian Agricultural Council, and it held its first meeting (in Melbourne) on the 31st July and the 2nd August, 1935. Those present were Mr. S. L. Allman and Mr. H. Broadfoot (New South Wales), Mr. F. M. Read and Mr. R. T M. Pescott (Victoria), Mr. R. Veitch (Chairman, *vice* Dr. A. J. Nicholson) and Mr. H. Barnes (Queensland), Mr. A. G. Strickland (South Australia), Mr J. W. Evans (Tasmania), and Mr. G. A. H. Helson (C.S.I.R.). (Owing to illness, Dr. A. J. Nicholson, who would also have represented C.S.I.R. was unable to attend.)

The main conclusions and recommendations of the Committee are outlined in the following paragraphs.

It is considered that a reasonable degree of codling moth control is obtainable by—(i) the regular application of a spray programme; (ii) the use of bandages; and (iii) strict attention to orchard hygiene. Further experiments are desirable to determine the accuracy of the luring method of ascertaining the correct time for spray applications.

The investigation of the particle size of lead arsenates is desirable. Despite the disappointing results that have so far attended the use of derris, it is felt that further research should be carried out with this material in combination with white oils having an acid reaction.

Any further spraying experiments should include the testing of such promising combinations as nicotine sulphate and bentonite-sulphur. (Arrangements have recently been made for the importation of a suitable quantity of bentonite-sulphur for experimental use, and inquiries have also been instituted regarding Australian deposits of bentonite-like clays.)

The Committee feels that further experiments should be conducted with the object of determining some standards to which spraying oils should conform. It also considers that the necessity for chemical studies of certain aspects of various insecticides, as indicated in some of the above recommendations, is further evidence of the desirability of C.S.I.R. appointing research chemists for special insecticidal studies.

It is considered that, in addition to field tests with insecticides, further laboratory work is necessary to determine the action of various insecticides both on the eggs and the larvae of the codling moth; also that work should be continued into the not infrequent occurrence of injury following the use of various codling moth spray schedules and chemically-treated bandages.

The Committee feels that, in view of the fact that the whole question of biological control of codling moth has been thoroughly investigated in the past without any degree of success being obtained, no useful purpose can be served at the present time by the initiation of further work in this direction.

Sheep Problems—Contributions by Australian Pastoral Research Trust.

The Australian Pastoral Research Trust Limited has recently undertaken to provide C.S.I.R. with a sum of £2,000 per annum for three years as from the 1st October, 1935, to match on a £1 for £1 basis contributions from the Commonwealth Government to render possible certain investigations into problems of outstanding importance to the Australian sheep industry. These include worm infestation, the value of phosphatic licks, drought feeding, coast disease, foot-rot, entero-toxaemia, and an extension of work on the blowfly problem.

For the past five years the Trust has been assisting the Council in a similar way. The recent increase in the knowledge of black disease in sheep, of caseous lymphadenitis, of pulpy kidney, and of the various problems mentioned above and on which work will continue, is in no small way due to the part played by the Trust.

Investigations on Bananas.

The following is an extract from the *Journal of the Royal Society of Arts*, 21st June, 1935:—

"A scheme for the improvement of the banana has been sanctioned by the Imperial Council of Agricultural Research, Delhi, at a cost of 74,000 rupees, spread over five years, in the first instance. The Banana Research Station will be located at Coimbatore, where considerable preliminary work has been done. The principal work will be to survey and classify different varieties, investigate the keeping qualities of the fruit, standardize the best methods of cultivation, conduct manurial experiments, select pure lines involving new and desirable types, study methods of transport, banana diseases and their control, and the preparation of banana products, such as flour, jam, preserves, &c."

A Review.

"Chronica Botanica.—An Annual Record of Pure and Applied Botany." Edited by F. R. Verdoorn. Editorial and publishing office: P.O. Box 8, Leiden, Netherlands.

When one realizes the truly amazing scope of botany as a science and as a fundamental in many applied sciences, it is evident that in these days two requirements are outstanding. One is the publication of works which give in accurate perspective the present state of knowledge in a given field. The other is the need to maintain some sort of contact with the 4,000 institutions, the 1,000 journals, and 60,000 or so men having to do with botany directly or indirectly throughout the world.

"Chronica Botanica" is a new publication which is planned to meet the second requirement. Obviously there were difficulties in securing all the desired information for the first year's issue, but these difficulties should be smoothed out with time.

The calendar of events and notes on conferences to be held are useful, particularly if they include an outline of the programme and the address of the secretary. The section dealing with the review of plant sciences in all countries contains much information otherwise quite difficult to reach. At present the relative values are disproportionate, but this will undoubtedly be remedied when adequate data from the various countries are supplied.

The section devoted to the addresses, new and changed, contains many which are neither new nor changed. In the opinion of the writer, this section is not so necessary, as addresses may be obtained from other sources, and it may tend to become a larger instead of a smaller section to the detriment of preceding and more important parts. A classified list of periodicals, &c., recognized as being botanical or as regularly publishing botanical material, would be at least as useful, if not more so.

Generally speaking, the new publication will be more useful to the general practitioner than to the high specialist, and will be convenient as a reference book to those in administrative and teaching positions.—

B.T.D.

Recent Publications of the Council.

Since the last issue of this *Journal,* the following publications of the Council have been issued:—

Bulletin No. 92.—"The Apple-Growing Soils of Tasmania." Part 1.—A General Investigation of the Soils, by C. G. Stephens, M.Sc. Part 2.—A Soil Survey of Part of the Huonville District, by J. K. Taylor, B.A., M.Sc., and C. G. Stephens, M.Sc.

This Bulletin contains the results of the work carried out by the Council's Division of Soils. In all, detailed descriptions of ten soil types or groups of soils are given, viz., Huon silty loam, Huon loam, Huon sandy loam, Huon sand, Mersey clay loam, Woodbridge sandy loam, Woodbridge loam, Grove sand, Lucaston sand, and alluvial soils. The reaction, buffer capacity, and replaceable bases were studied in some detail, and yielded useful information concerning the response of the soils to lime. Nitrogen was determined on all surface soils, better tree growth, in general, being characterized by higher nitrogen values. The work done also indicated that the phosphoric acid requirement of the trees is small and satisfied by the amounts available, and that tree vigour is weakly, but definitely, correlated with potash content. The influence of the various soil types on horticultural features is discussed in full with comments on specific soil problems, such as hardpan formations and drainage.

Pamphlet No. 56.—"The Occurrence of Bovine Babesiellosis in Northern Australia," by J. Legg, B.Sc., D.V.Sc., M.R.C.V.S.

The work discussed in this Pamphlet forms a part of a programme of investigation which was originally put in hand as a co-operative enterprise of the former Empire Marketing Board, the Queensland Department of Agriculture and Stock, the cattle-owners of Queensland, the Queensland Council of Agriculture, and the Council for Scientific and Industrial Research The investigations are centred at the Animal Health Laboratory, Oonoonba, near Townsville. The organism discussed is *Babesiella argentinum,* and is one of four blood parasites that are now known to cause "tick-fever" in Queensland. The work discussed in the report is of particular significance in the control of "tick-fever" in Australia. For example, when attempts are made to protect cattle about to be transferred from "clean" to tick-infested zones, due account must be taken of the possibility of infection by *B. argentinum,* as well as by the other protozoan blood parasites known to occur in Queensland.

Pamphlet No. 57.—"Tests of the Efficacy of the Oxy-acetylene Scouring and Charring process for Sterilizing Partly-decayed Poles," by J. E. Cummins, M.Sc.

The oxy-acetylene process of treating a partly-decayed pole consists briefly of removing the earth or other filling around the pole to a depth of 12 to 18 inches, removing any sapwood or areas of bad decay, and scouring cracks containing decay by an oxy-acetylene flame. After charring the pole for a distance of about 12 inches above and below the ground line, and while the pole is still hot, creosote previously heated to about 160° F. is applied, using a fine cone-shaped spray. The Pamphlet discusses laboratory tests of the efficacy of the process. After treatment of experimental poles, sections were taken to the laboratory

and tested for the existence of live decay organisms. It was found that the creosote oil application was intimately associated with the degree of sterilization, and that its use was essential to the best results being obtained from the process. No field service tests were made, and the economics of the process are not discussed.

Pamphlet No. 58.—"Certain Aspects of Investigations on Black-end Disease of Bananas in Australia," by Shirley Hoette, M.Sc.

This publication concerns work carried out in the Botany Department of the University of Melbourne under the supervision of Professor A. J. Ewart and Dr. E. McLennan. The different types of black-end are defined, and the fungi associated with these conditions are discussed. *Gloeosporium musarum* is of first importance, and three strains of this fungus, together with several strains of the associated ascosporic stage, *Glomerella cingulata,* are described, and their affinities with American and European species pointed out. Black-end, however, is also caused by *Nigrospora Musae, Thielaviopsis paradoxa,* and *Fusarium* spp.

Forthcoming Publications of the Council.

At the present time the following future publications of the Council are in the press:—

Bulletin No. .—"Radio Research Board: Report No. 9."

Bulletin No. .—"Radio Research Board: Report No. 10."

Bulletin No. .—"Fertility in Sheep: Artificial Production of Seminal Ejaculation and the Characters of the Spermatozoa Contained Therein," by R. M. C. Gunn, B.Sc. (Agric.), D.V.Sc., M.R.C.V.S. (Lecturer in Veterinary Anatomy, Surgery, and Obstretrics at the University of Sydney).

Bulletin No. .—"Studies in Bovine Pleuro-Pneumonia.—I. A Study of the Morphology and Life Cycles of the Organism of Pleuro-Pneumonia Contagiosa Boum (*Borrelomyces peripneumoniae,* nov. gen.) by Observation in the Living State under Dark-ground Illumination," by A. W. Turner, D.Sc., D.V.Sc.

Bulletin No. .—"Studies in Bovine Pleuro-Pneumonia." II., III., and IV. II.—A Complement-fixation reaction for the Diagnosis of Contagious Bovine Pleuro-Pneumonia, by A. D. Campbell, B.V.Sc., and A. W. Turner, D.Sc., D.V.Sc. III.—Observations on the Diagnosis of Contagious Bovine Pleuro-Pneumonia by means of the Complement-fixation Tests of Campbell and Turner, by H. R. Seddon, D.V.Sc. IV.—The Complement-fixation Test of Pleuro-Pneumonia, by H. Albiston, D.V.Sc.

Pamphlet No. .—"A Study of Persistence in Certain Introduced Pasture Grasses," by A. McTaggart, M.S.A., Ph.D.

Pamphlet No. .—"A Report on a Survey of Weed Problems in Australia," by G. A. Currie, B.Sc., B.Agr.Sc.